A Novel Video and Acoustic Survey of the Seaweeds of Lennox Passage and St. Peters Bay, Cape Breton, Canada

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A NOVEL VIDEO AND ACOUSTIC SURVEY OF THE SEAWEEDS OF LENNOX PASSAGE AND ST. PETERS BAY, CAPE BRETON, CANADA

by

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TABLE OF CONTENTS

	Page
LIST OF TABLES	iv
LIST OF FIGURES	v
ABSTRACT / RÉSUMÉ	vi
INTRODUCTION	1
MATERIALS AND METHODS	3
RESULTS	5
DISCUSSION	10
ACKNOWLEDGEMENTS	15
REFERENCES	15

LIST OF TABLES

	Page
Table 1: Species list.	19
Table 2: Towfish bottom classification codes.	21
Table 3: Towfish canopy classification codes.	22
Table 4: Sample towfish ground truth data.	23
Table 5: Towfish bottom type data by zone.	25
Table 6: Towfish canopy type data by zone.	26
Table 7: 5m bottom type cross points.	27
Table 8: 10m bottom type cross points.	29
Table 9: 20m bottom type cross points.	31
Table 10: Summary VH bottom type classification by zone and depth.	32
Table 11: 5m canopy type cross points.	33
Table 12: 10m canopy type cross points.	36
Table 13: 20m canopy type cross points.	38
Table 14: Final VH canopy type classification by zone and depth.	39
Table 15: Location and description of sampling stations.	40
Table 16: Biomass data for shore and 5 m sampling stations.	44
Table 17: Biomass data for 10 and 20 m sampling stations.	46
Table 18: *Saccharina* standing stock estimates.	48

LIST OF FIGURES

	Page
Figure 1: The study area.	49
Figure 2: The survey area divided up into six zones.	50
Figure 3: Typical results of towfish bottom type data.	51
Figure 4: The same towfish track with the macrophyte classification.	52
Figure 5: Sidescan imagery associated with different bottom types.	53
Figure 6: Bottom type screen shots.	54
Figure 7: Macrophyte screen shots.	55
Figure 8: The survey area indicating the tracks of the echosounder.	56
Figure 9: VH bottom detection line and macrophyte detection line.	57
Figure 10: VH bottom classification crossing towfish transect T7.	58
Figure 11: Ground truthing for VH macrophyte canopy classification.	59
Figure 12: Sampling stations.	60
Figure 13: Echogram indicating large thalli of *S. latissima*.	61
Figure 14: Detail of echogram.	62
Figure 15: Shore stations.	63
Figure 16: Buffer created along the 5m VH scores for canopy height.	64

ABSTRACT

Vandermeulen, H., Wilson, M. and B. Hymes. 2017. A Novel Video and Acoustic Survey of the Seaweeds of Lennox Passage and St. Peters Bay, Cape Breton, Canada. Can. Tech. Rep. Fish. Aquat. Sci. 3194: vii + 64 p.

A novel, bay – scale (i.e. tens of km) survey method was employed to examine algal populations on the southwestern shore of Cape Breton, Canada, for the purposes of potential economic exploitation. Since traditional remote sensing methods were unlikely to be successful in these waters, underwater video and acoustic methods were applied. A transponder positioned towfish housing video camera and sidescan sonar was hauled along predetermined transects perpendicular to shore to provide information on bottom type and algal cover. The towfish data were used to ground truth echosounder data (bottom type and macrophyte canopy height) collected along 5, 10 and 20 m depth contours. The survey area was divided into six zones comprising a range of exposure, depth and bottom types. Destructive quadrat samples were collected at each depth plus shore stations to provide biomass estimates. Over thirty five taxa were enumerated, indicating depths and zones of common occurrence. *Ascophyllum* was abundant at some of the shore stations. The genera *Chondrus, Cystoclonium, Desmarestia, Fucus, Phyllophora, Polysiphonia,* and *Saccharina* were common at 5 m. *Desmarestia* and *Saccharina* dominated at 10 m with wet weights sometimes over 1 $kg \cdot m^{-2}$. *Agarum* dominated at 20 m. The towfish / echosounder grid sampling system was relatively coarse in order to cover the 140 km^2 survey area within 12 days. As a result, the survey did not produce spatially detailed information. However, adequate information was gathered to describe the general characteristics of bottom type and algal cover by zone and for focussing further exploration.

RÉSUMÉ

Vandermeulen, H., M. Wilson et B. Hymes. 2017. Nouveau relevé vidéo et acoustique des varechs du passage Lennox et de la baie St. Peters, au Cap-Breton, au Canada. Rapp. tech. can. sci. halieut. aquat. 3194: vii + 64 p.

Une nouvelle méthode de relevé, à l'échelle de la baie (c.-à-d. des dizaines de kilomètres), a été utilisée pour étudier les populations d'algues de la côte sud-ouest du Cap-Breton, au Canada, aux fins d'exploitation économique potentielle. Étant donné que les méthodes traditionnelles de télédétection étaient peu susceptibles de donner de bons résultats dans ces eaux, le relevé a été effectué en utilisant la vidéo et les méthodes acoustiques. Un poisson, positionné par transpondeur, et dans lequel avaient été placés une caméra vidéo et un sonar à balayage latéral, a été remorqué le long de transects prédéterminés, perpendiculaires au rivage, pour fournir des renseignements sur le type de fond et la couverture d'algues. Les données du poisson ont été utilisées pour vérifier les données de l'échosondeur (type de fond et hauteur de la couverture de macrophytes) recueillies le long des isobathes de 5, 10 et 20 mètres. La zone de relevé a été divisée en six zones constituées d'une catégorie d'exposition, d'une profondeur et de types de fonds. Des échantillons ont été recueillis au moyen de techniques destructives à chaque profondeur dans les quadrats ainsi qu'aux stations à terre afin de fournir des estimations de la biomasse. Plus de trente-cinq taxons ont été dénombrés, qui ont indiqué les profondeurs et les zones dans lesquelles la présence des algues était fréquente. Le genre *Ascophyllum* était abondant à certaines des stations terrestres. Les genres *Chondrus*, *Cystoclonium*, *Desmarestia*, *Fucus*, *Phyllophora*, *Polysiphonia* et *Saccharina* étaient fréquents à 5 mètres, tandis que les genres *Desmarestia* et *Saccharina* dominaient à 10 mètres, avec des poids humides parfois supérieurs à 1 kg·m-2. Enfin, le genre *Agarum* dominait à 20 mètres. Le système d'échantillonnage par grille du poisson/échosondeur était relativement grossier afin de couvrir la zone de relevé de 140 km^2 dans un délai de 12 jours. Par conséquent, le relevé n'a pas permis d'obtenir des renseignements détaillés sur le plan spatial. Cependant, des renseignements pertinents ont été recueillis pour décrire les caractéristiques générales sur le type de fond et la couverture d'algues par zone afin d'orienter une étude plus approfondie.

INTRODUCTION

Nova Scotia has a long history of commercial exploitation of seaweeds, particularly in the southwestern portion of the province (Vandermeulen 2013a). The senior author was contacted by industry regarding their interest in exploring the potential for commercial harvest in Cape Breton, a region of the province not normally harvested intensively for a variety of economic reasons. Potential genera included the traditionally harvested brown alga *Ascophyllum*, along with any locally abundant algal species which may provide novel products. After a preliminary investigation, it was decided to focus upon the southwestern section of the island due to its potential for suitable algal biomass (mixed wave exposure, islands and reef areas), relative distance to larger population centers, and existing / potential infrastructure for landings and transportation. The next step, as described in this paper, was a survey of the algae in the area.

Traditionally, nearshore surveys of benthic habitat (including algae) have been performed by intertidal or SCUBA based transects. For example, Parsons et al. (2004) utilized GPS positioned diver video transects to create a detailed bottom habitat map in a small bay in New Zealand. The classification included a variety of algal habitats. The area they surveyed was small, however (less than 1 km^2), and the level of effort required to sustain that intensity of survey in an area as large as the southwestern portion of Cape Breton would be prohibitive.

Remote sensing has often been used to assess and map algal biomass in the nearshore and these methodologies can work very well in the intertidal zone or if the canopy reaches the sea surface, as is the case for some of the larger kelps (Stekoll et al. 2006). However, the utility of remote sensing in some of the more turbid, low tidal range waters of Atlantic Canada is debatable (Vandermeulen 2011a, 2014). There remains a steady chorus of researchers either challenging the accuracy of satellite or air photo based remote sensing methods for detecting benthic habitat features at depth (e.g. Shao and Wu 2008) or suggesting that acoustic methods may be more appropriate for this purpose (Sabol et al. 2002, 2009; Komatsu et al. 2003; Hewitt et al. 2004; Parsons et al. 2004; Barrell and Grant 2013). In our experience, Chamberlain et al. (2009) quite correctly state that acoustic methods detect considerably more submerged aquatic vegetation than aerial photographic methods, and the biomass detection also occurs to a greater depth.

Although acoustic methods have most commonly been used to describe bottom characteristics such as hardness or rugosity, or habitat features associated with benthic invertebrates (e.g. Moore et al. 2009), there have also been ongoing efforts to map aquatic macrophytes. Earlier studies utilizing single beam echo sounders to determine the presence or cover or biomass of aquatic macrophytes simply visually interpreted echosounder paper tracings to identify signals indicating macrophytes. Duarte (1987) used echosounder tracings to obtain biomass estimates of vascular macrophytes in lakes based upon canopy height. Spratt (1989) also used echosounder tracings to determine eelgrass distribution in Tomales Bay, California.

More recently, sidescan sonar has been successfully applied to survey seagrass beds (Mulhearn 2001; Stolt et al. 2011; Vandermeulen 2014) and crustose coralline algal beds (Pereira-Filho et al. 2012). Modern multibeam echo sounding has also found its

place. McGonigle et al. (2011) utilized multibeam backscatter to specifically target the canopy volume of deep-water benthic macroalgae including *Laminaria* and *Agarum*. Abukawa et al. (2013) used multibeam echo sounding to assess the canopy height and biomass of aquatic vegetation in a lake to a depth of about 20 m. Komatsu et al. (2003) used multibeam to map *Zostera caulescens* bed volumes in shallow waters (< 10 m) in Japan. Using slightly different methods, Che Hasan et al. (2014) created habitat classes that included mixed brown, red and green algae via multibeam echo sounding backscatter measures. They were working down to depths of 80 m in Discovery Bay, Australia.

Single beam echosounder technology, both hardware and software, has improved greatly since the days of paper tracings. Anderson et al. (2002) used an echosounder running QTC VIEW software to discern macroalgae on rock, primarily *Laminaria*, *Agarum* and *Chondrus,* in the coastal waters of Newfoundland. Jordan et al. (2005) used two different echosounders on different vessels to map inshore and offshore seabed habitats for potential MPA designation in south-east Australia. They were able to classify both seagrass (*Halophila*, *Posidonia*, *and Zostera*) and dominant brown algae (*Phyllospora*, *Ecklonia*).

BioSonics Inc. is the only company that produces echosounder hardware and software specific for the detection of aquatic macrophytes. Their digital echosounders (mainly the DE and DT model series) and transducers (narrow beam, 6° or less; ~200, 420 or 430 kHz) have been used widely to assess rooted vascular macrophytes in marine and freshwaters. EcoSAV™ software is proprietary to the company, and provides an analysis of canopy height and cover from the echosounder data. BioSonics-based surveys have included both tropical and temperate seagrasses (Marbà et al. 2002; Sabol et al. 2002; Tegowski et al. 2003; Chamberlain et al. 2009; Stevens and Lacy 2012; Barrell and Grant 2013) and macrophytes in lakes (Thomas et al. 1990; Leisti et al. 2006; Winfield et al. 2007; Istvánovics et al. 2008; Sabol et al. 2009; Valley et al. 2010; Herbst et al. 2013).

All of the acoustic based examples mentioned above utilize some form of ground truthing to differentiate an acoustic macrophyte signature from an acoustic substrate signature. Typically, ground truthing is performed via rake or other destructive sampling, SCUBA observations, drop cameras, towed video or remotely operated vehicle.

With the above background information in mind, it was decided to perform the Cape Breton survey utilizing a novel combination of equipment and new methods which avoided the inherent problems of aerial remote sensing. A towfish combining video and sidescan hardware was run along transects to ground truth BioSonics-based echosounder data collected along depth contours. The novelty of the method stems from the fact that our devices are nested in scale, from video to sidescan to echosounder, each device in that sequence providing ground truth data for the next – culminating in the echosounder tracks which covered the greatest possible geographic area. The complete survey was set to occur during the summer months to coincide with peak algal diversity and biomass, and the traditional timing for potential commercial harvest.

2.0 MATERIALS AND METHODS

2.1 Study Site

The island of Cape Breton is the northeastern extension of the province of Nova Scotia, Canada. Lennox Passage is found in the south of Cape Breton, between the Cape Breton shore to the north and Isle Madame to the south (Fig. 1). The passage extends to the east towards St. Peters Bay, which has a canal entering into Bras d'Or Lake – a large estuary in the interior of Cape Breton.

The western end of Lennox Passage at Rabbit Island is a moderately exposed area opening out into Chedabucto Bay to the south. As one moves east from Rabbit Island through the passage the waters rapidly become calmer and more protected. From the midpoint of Lennox Passage and heading further east the waters gradually become more exposed again, eventually opening up into a wide bay broadly exposed to deep ocean swells coming from the open Atlantic. The easternmost headland of the bay is Red Point. Our survey incorporated the area from Rabbit Island through to Red Point.

2.2 Towfish Survey

A novel towfish was deployed as described in Vandermeulen (2011a; 2013b; 2014). Briefly, the towfish consisted of a video camera with 10cm laser scale and a 330 kHz sidescan sonar set to a 30 m swath width. The video feed was used to ground truth the sidescan imagery in real time. The towfish was positioned to sub-meter precision via a transponder / transceiver system coupled to a high end dGPS with Canadian Coast Guard beacon correction. During the survey, the towfish was hauled behind the vessel from depth to the shallows on transects perpendicular to shore. Some transects were run from shore to an opposite shore. The vessel speed over ground during transect runs was approximately 1.5 knots. The towfish was held approximately 30 cm off of the bottom at all times. In this position, the field of view of the camera was approximately 1 m.

The survey area was divided into six zones, with at least two transects per zone (Fig. 2). The zones were chosen to reflect differences in depth and exposure within the survey area. Zone 1 was moderately exposed with depths to just over 10m with a water surface area of approximately 12 km^2; Zones 2 and 3 were much more protected and shallower (approximately 9 and 7 km^2 respectively); Zone 4 was a transition area where Lennox Passage widened and became deeper (>10m) and more exposed, it had a surface area of 22 km^2; Zone 5 was a broad exposed area with depths >20m and a surface area of approximately 37 km^2; and Zone 6 was a large, deep open bay with extreme exposure (large swells from the open Atlantic). Its water surface area was approximately 52 km^2.

Post processing of towfish data was accomplished via the use of specialized commercial software (Vandermeulen 2011a). A MapInfo GIS project was created with a hydrographic chart background layer in which sidescan GeoTIFF images, towfish track positions (which were updated every 1.3 seconds) and AVI video clips were embedded. Each video clip was approximately 10 min long and embedded into its starting point on the associated GeoTIFF image. In this manner, each transect was assigned a number

and then divided up into sections defined by the associated video clips. For example, transect number 3 in the section covered by video clip number 5 would be coded as T3S5. By examining the sidescan imagery in a particular section of the transect and comparing it to the video clip for that section, it was possible to classify bottom types and macrophyte types associated with each towfish track position. The resulting towfish based classification was used to ground truth the echosounder survey that followed.

2.3 Echosounder Survey

Independently of the towfish transects, an echosounder system was deployed as described in Vandermeulen (2011b). The BioSonics Inc. (Seattle, WA 98107) system consisted of a DT-X digital echosounder surface unit, a 210 kHz single beam digital transducer with 6° cone angle, and a 430 kHz single beam digital transducer with 6° cone angle and built in heading / pitch / roll (HPR) sensor. The transducers were chosen for their ability to detect bottom type and macrophyte cover, respectively. Both transducers operated at the same time, with alternating ping cycles. The echosounder track was recorded to sub-meter precision via the same dGPS unit used for the towfish. During the survey, hydrographic chart contour lines were followed to get relatively uniform sized ping foot prints for better precision in later data analyses (Vandermeulen 2011b). The vessel speed over ground was approximately 4 knots, similar to Sabol et al. (2009). In order to maximize the ability to pick out different types of algal assemblages, 5, 10 and 20m contours were chosen for this survey.

Data processing was accomplished via specialized software from BioSonics, Inc. (Vandermeulen 2011b). Visual Bottom Typer™ was applied to the 210 kHz dataset and EcoSAV™ to the 430 kHz dataset. Later on, both datasets were revisited with Visual Habitat™ software, an update incorporating and enhancing the properties of the previous two software packages.

2.4 Quadrat Survey

Data from the towfish and echosounder surveys was extracted to determine sites for SCUBA based destructive sampling for standing stock data on dominant algal species. An effort was made to select representative algal communities at 5, 10 and 20 m depths along towfish transects based upon the video data. The survey design was not random; it was an attempt to discern areas with notable algal cover for potential commercial harvest. The survey effort was divided into the three depths plus shore stations in order to maximize the ability to explore different types of algal communities.

1 m^2 and 0.25 m^2 quadrats were constructed from aluminum angle, and paint scrapers were used to remove all algae within each quadrat at each sampling station. A slurp gun was used to remove delicate algal forms which could not easily be stuffed into a collection bag after scraping (Vandermeulen et al. 2011). Three quadrats of equal size were used at each sampling station. The quadrats were deliberately placed by the divers to obtain a representative sample of the attached algal flora in the immediate area. Material from each quadrat was placed into individually labelled sampling bags, repackaged in the dive boat and placed into coolers for transport. That same evening,

the algal samples were spun in a mesh bag or in a salad spinner to remove surface moisture. Material from each quadrat was sorted by species and a wet weight per species was obtained. Rare species, where wet weight was less than 1 g, were ignored. The weight of epiphytes was also ignored; the epiphyte load was light in any case. In some instances, subsamples were preserved in formalin and taken back to the lab for later sorting and weighing or to confirm taxonomy. Average weights were calculated from the three quadrats for each algal species at each station.

3.0 RESULTS

3.1 Species List

The algal and other macrophytic species found during this study are listed in Table 1.

3.2 Towfish Survey

The survey ran from June 8-10, 2010. Sixteen transects were completed, covering a total distance of approximately 26 km and a total zonal surface area of approximately 140 km² (Fig. 2). Although the weather was rough and the water was turbid, good data were obtained by the towfish overall. Figure 3 provides an example of bottom type results at the north end of transect 1 (T1), with the shoreline indicated in tan color at the top of the figure. The hydrographic chart background is useful for interpreting the towfish data. Note how our vessel was able to obtain sidescan and video data in waters <1m deep. In this example, the substrate transitions from a soft muddy bottom (low acoustic reflectivity, dark brown sidescan image) into a coarse gravel bottom (high acoustic reflectivity, light 'brassy' sidescan image) at a depth of about 10m from Canadian Chart Datum (essentially a point below which the tide rarely falls). The sidescan imagery was ground truthed via the associated video clips to generate the bottom classification seen in the midline of the transect. The midline represents the actual position of the towfish during the haul, and each colored symbol is a towfish position data point generated by the towfish transponder / transceiver system. The macrophyte classification for this same portion of the bottom is shown in Fig. 4. As would be expected, the deeper soft muddy bottom has no macrophytes while the coarse gravel bottom sports *Saccharina* in its deeper portion with *Fucus* in the shallows. A thin band of *Z. marina* was also seen in the shallows on the gravel.

Different bottom types were recognizable with the sidescan imagery (Fig. 5). A dark, featureless sidescan image indicates a soft bottom of low acoustic reflectivity (Fig. 5a). The two bright bands on either side of the sidescan image are artifacts. Figure 5b demonstrates the much higher acoustic reflectivity of coarse sand, resulting in a much brighter image which is also relatively flat and featureless (there are a couple of larger boulders in the lower left of the image, note the long dark acoustic 'shadows' they create). A bright image with more 'texture' or features is seen in Fig. 5c, constituting a gravel base with scattered mid-sized cobble (note the numerous small acoustic shadows). The greatest amount of texture is seen on boulder / cobble bottoms, with

many long acoustic shadows covering the image (Fig.5d). All bottom types indicated by the sidescan imagery were confirmed by the associated video at the same location (Fig. 6). It was also possible to identify different groups of macrophytes via the video feed (Fig. 7).

The video and sidescan information from the towfish was used to create both a bottom classification (Table 2) and a macrophyte or canopy classification (Table 3). The canopy classification shown in Table 3 was driven by an attempt to find associations of algae where one species would dominate with a cover of ≥ 50%. In deeper areas with many bare patches of substrate, *Agarum* would occasionally dominate as the main algal species but it's cover did not approach 50%. However, *Agarum* and its assemblage of species did constitute a valid canopy class and was given a canopy code of four (Table 3). The term 'crozier morph' has been associated with the taxon *Laminaria longicruris* Bach. Pyl. in the past (Sears 2002). It refers here to thalli of *S. latissima* with elongated stipes of various degrees of inflation (Chapman 1973; 1974).

Table 4 is a summary derived from a spreadsheet of towfish data associated with survey zone, transect number, time stamp, depth, latitude and longitude of the towfish at the time stamp; and bottom type plus canopy codes at that towfish position. 22,915 of these ground truth point records were created from the towfish survey data.

The towfish ground truth point records were used to derive the proportion of bottom types recorded by towfish survey zone, not binned by depth. The resulting summary (Table 5) provides a general overview of bottom types which are consistent with the hydrography of each zone. For example, zones 1 – 4 were the more sheltered zones of the survey and they were dominated by soft mud / silt (bottom type #1) with no hard boulder / reef areas (bottom type #5) and very little or no hard sand / silt areas (bottom type #2). Zone 5 was a transitional area depth and exposure wise, and it had a relatively even proportion of each of the bottom types (Table 5). Zone 6 had the greatest depth and exposure, and no soft bottoms were recorded by the towfish in that zone.

Table 6 is a summary of the proportion of canopy types in each towfish survey zone, also not binned by depth. Once again, the results are consistent with the hydrography of each zone. The zone with the most even proportions of all bottom types also had the most even proportions of all canopy types, Zone 5. It was also the only zone not missing any canopy types. Zones 1 – 3 were notable for their relative absence of macrophytes, having no consistent macrophyte cover over 80% of the time (canopy type #6). This is reasonable, considering that >76% of the surveyed bottom in these zones was soft mud or silt (Table 5). Zone 6 was the only zone missing *Zostera* (canopy type #3), consistent with the high degree of wave exposure in the zone. *Agarum* (canopy type #4) was the dominant macrophyte in Zone 6. There was also a considerable amount of completely or partially bare bottom, as would be expected for the overall greater depths found in Zone 6.

3.3 Echosounder Survey

The survey was completed during June 21-24, 2010. Rough weather plagued this survey as well, although the echosounder system held up and the data were useful. The

tracks of the echosounder data acquisition are indicated in Fig. 8. A corrupted data file led to a gap in coverage on the 10m contour in the middle of Zone 4. A total of approximately 80 km of coastline was covered by the survey.

Both Visual Bottom Typer™ and EcoSAV™ software packages are loaded with echogram files, parameters are set for analysis, and data processing occurs in a batch mode. If the results from these packages seem odd or inconsistent with towfish ground truth data, the operator must reset the parameters based upon past experience or other opinions as to what might improve the results. Although the results from Visual Bottom Typer™ and EcoSAV™ on the 210 and 430 kHz datasets were reasonably consistent with the towfish ground truth data, a decision was made to revisit both datasets with more recent and updated Visual Habitat™ (VH) software.

The value of the VH software is the ability to edit echograms. The software selects bottom detection and macrophyte detection lines automatically, and these lines can be edited (Fig. 9). Editing allows for the correction of errors in the creation of the original detection lines such as false positives for a macrophyte canopy. Softer bottoms occasionally generate these false positives and they are easily recognized in the echograms. After editing, VH can process the echograms to detect different types of acoustic signatures associated with different bottom types, or estimate the canopy height of macrophyte cover. In other words, VH includes the functions of both Visual Bottom Typer™ and EcoSAV™ in one software package.

After some experimentation with VH , it was determined that setting the software to search for six types / classes of acoustic signatures to associate with different bottom types provided quite robust results for comparison to towfish ground truth data. Similarly, binning the canopy height results into three different categories seemed most satisfactory.

Echosounder ground truthing was obtained by examining cross points with towfish transects. In Fig. 10, there are seven VH points crossing the sidescan image and the associated towfish classification. The VH classification matches the towfish classification at this cross point. Ground truthing for macrophyte cover was analysed in a similar manner, focussed upon canopy height bins. In Fig. 11 there are eight VH classification points covering the sidescan imagery. Two of those points match a canopy height of 0.5 to < 1.6 m, while the rest are associated with the canopy height bin of 0.2 < 0.5 m. All eight VH classification points are consistent with the towfish canopy classification of *Saccharina* at this cross point.

The results of the ground truthing exercise for the 5m contour bottom type survey are shown in Table 7. All towfish bottom type classes were seen at cross points with the echosounder tracks at 5m, except towfish class 2 (hard – sand / silt). In Table 7, the class of acoustic signatures most commonly associated with towfish class 1 (soft) is VH class 1. Echosounder based VH class 1 signatures were also occasionally associated with the other towfish classes, but not strongly. VH class 2 signatures appeared to be transitional, spanning the full range of towfish classes while not being particularly strongly associated with any one towfish bottom type class. VH classes 3, 4 and 5 were not found on any bottom cross points with a towfish class 1 bottom. In other words, these three VH classes were exclusive to harder bottoms. VH class 6 was only seen

once. On the basis of these observations, the VH classes were used to create three different color coded echosounder based bottom types in the GIS: 'soft' (VH class 1 points, coded red); 'hard' (VH classes 3, 4, 5, coded blue); and 'undetermined' (VH classes 2 & 6, coded clear). The three color codes made sense in the GIS, where softer (red) bottoms at 5 m were associated with quieter shores and harder (blue) bottoms were associated with exposed points or current swept areas.

A similar analysis was performed at the 10 m contour (Table 8). VH class 1 was not seen at any transect cross point. VH classes 2, 3, 4 were associated with harder bottoms. VH class 5 was rather randomly associated with both hard and soft areas. VH class 6 was only found on softer bottoms. On the basis of these observations, the VH classes were used to create three different color coded echosounder based bottom types in the GIS for 10 m: 'soft' (VH class 6 points, coded red); 'hard' (VH classes 2, 3, 4, coded blue); and 'undetermined' (VH classes 1 & 5, coded clear). The three color codes also fit in the GIS, where softer bottoms were associated with quieter shores or when the vessel strayed into deeper areas and harder bottoms at 10 m were associated with the more exposed areas in Zone 6.

The echosounder data analysis for 20 m was problematic (Table 9). There were fewer cross points with towfish transects to work with compared to 5 or 10 m. VH class 1 was associated with flat sediments of varying hardness. VH class 2 associations were inconclusive. VH class 3 was associated with harder bottoms, while VH class 4 seemed to pick up the acoustic signal associated with the coarse texture of gravel. VH classes 5 and 6 were not found at cross points at 20 m. As above, three different color coded echosounder based bottom types were added to the GIS for 20 m: 'flat' or featureless sediment of varying hardness (VH class 1 points, coded red); 'hard or textured' (VH classes 3 & 4, coded blue); and 'undetermined' (VH classes 2, 5, 6 coded clear). Qualitatively, the three color codes appeared to be reasonable in the GIS, matching expectations of depth and hydrography plus exposure.

The echosounder data and associated VH bottom classification analysis provided a mechanism to examine bottom types by zone and depth (Table 10). The proportion of unclassified (or clear) points in the GIS ranged from 10.5 to 56.3% - so an interpretation of this analysis is tentative at best. However, the general patterns of hard versus soft bottom identified by the analysis do seem logical. At the 5 m depth contour, Zone 6 had the highest proportion of hard versus soft bottom (proportion of blue versus red points in the GIS). This is consistent with the high degree of wave exposure in Zone 6. Zones 1 and 5 also had a relatively higher proportion of hard bottom at the 5 m depth contour, matching their exposure regime relative to Zone 6. At the 10 m depth contour, Zone 6 continued to have a very high ratio of hard to soft bottom – a pattern followed by Zone 5. Although the data for the 20 m depth contour were limited, it was interesting to see that Zone 6 was dominated by a rugose or textured bottom (many blue colored dots in the GIS) consistent with the coarse gravel or boulders seen in that area.

Towfish data were also used to ground truth VH canopy analyses. The results for the 5 m depth contour are seen in Table 11. The tallest plants at this depth contour were 2.54 m tall. The smallest bin of canopy sizes was 0 – < 0.2 m, which is classed as the detection limit for this VH analysis as echosounder cross points with towfish class 6 (100% bare) almost completely fall within this bin. *Fucus* was detectable within the next

VH canopy bin (0.2 - < 0.5 m), along with *Saccharina* and *Zostera*. The tallest canopy bin (0.5 – 3 m) was exclusively linked to the presence of *Saccharina*.

Table 12 is a summary of the 10 m canopy classification. The tallest plants at this depth contour were 1.58 m. The shortest VH canopy bin (<0.2 m) is considered to be the detection limit here again, as it is most commonly associated with towfish classifications 5 or 6 (70% or 100% bare). The tallest canopy bin (0.5 - 1.6 m) was exclusively associated with the presence of *Saccharina*. The intermediate VH canopy bin (0.2 – < 0.5 m) was associated with *Saccharina*, *Agarum*, and even sponge (T7 south cross point). Rarely, this canopy bin was captured even in the complete absence of algal material (T10 cross point) constituting a detection limit error in the VH canopy analysis.

As in the 20 m bottom type analysis, the canopy type analysis at this depth contour suffered from a lack of cross points for comparisons between towfish and VH analyses (Table 13). The shortest VH canopy bin was associated with towfish class 6 (100% bare), while the presence of *Agarum* was usually captured in the midsize VH canopy bin. The tallest VH canopy bin was not captured at any cross point at 20 m. However, the VH analysis indicated the presence of plants as tall as 2.05 m in other areas of the GIS at this depth contour.

A summary of canopy type classification by zone and depth is provided in Table 14. These results are consistent with the bottom type classification summarized in Table 10. For example, those zones and depths with greater than 80% of canopy in bin height < 0.2 m (essentially no macrophyte cover) in Table 14 are also the zones and depths with a 'blue to red' ratio of <1 in Table 10. In other words, areas with little or no macrophyte cover are also dominated by softer sediments or relatively featureless bottoms with little relief. Conversely, those areas with over 50% of canopy in bin height > 0.2 m (areas with a substantial amount of macrophyte cover) in Table 14 are also the zones and depths with a 'blue to red' ratio of >4 in Table 10. Areas with hard and textured bottoms had a greater macrophyte canopy.

3.4 Quadrat Survey

The quadrat survey ran from July 10-14, 2010. Rough weather continued, particularly in the eastern end of the survey area, but it was possible to complete the survey by accessing specific dive sites during clear weather windows. Table 15 and Fig. 12 provide the location and description of the various sampling stations. Station B – 2 was selected on the basis of echosounder information. The echogram at the 5 m contour in this area indicated large algae with lacunae, most likely the crozier morph of *S. latissima* with an inflated stipe (Figs. 13 & 14). Images of the shore stations are shown in Fig. 15.

The shore stations were almost completely dominated by *Ascophyllum* and species of *Fucus*, particularly *F. vesiculosus* (Table 16). The only shore without accumulations of *Ascophyllum* was 8-S (Fig. 15c). Sampling stations 10 – 5 – 2 and 10 – 5 – 3 were the only 5 m stations with *L. digitata*. These stations also comprised the most diverse and abundant algal flora of the 5 m stations (Table 16). The most cosmopolitan taxa at 5 m were *Ceramium, Phyllophora* and *S. latissima*. The commercial species *C. crispus* was found in moderate amounts at most of the 5 m stations. The only species of *Fucus*

found at 5 m was *F. serratus* and its biomass rivaled that of the kelps, a pattern common for this taxon in the northern portions of Nova Scotia. As predicted by the echograms, station B – 2 had an extraordinarily high biomass of *S. latissima* at 14 $kg \cdot m^{-2}$ wet weight (Table 16). The thalli were very long (many over 2 m) with long inflated stipes and a crozier morph.

Table 17 provides biomass data for the 10 and 20 m stations. The 10 m stations contained a fairly diverse flora although at biomass levels lower than that found at 5 m. *Saccharina latissima* was found at all 10 m stations but not at the 20 m depth contour. The two 20 m sampling stations displayed a sparse but distinctive algal flora. *Agarum clathratum* was predominant, while *Odonthalia dentata* and *Ptilota serrata* were only found at this depth and nowhere else.

Overall, the video descriptions of the sampling stations provided in Table 15 were quite consistent with the biomass data provided in Tables 16 and 17. Dominant algal taxa in the video tended to dominate biomass in the destructive quadrat samples.

3.5 Standing Stock Estimates of *Saccharina*

It was possible to use the buffer strip capability of the GIS to estimate areas of *Saccharina* cover along specific depth contours (Figure 16). A buffer width of 40 m was chosen as a conservative estimate of the region along a particular depth contour (5 or 10 m) where a reasonably consistent cover of *S. latissima* associated with that depth would occur. For simplicity, it was assumed that all macrophytes taller than 0.5 m would most likely be *Saccharina* within the buffer strips at those two particular depth contours. Finally, average wet weight values for *Saccharina* at those two depths were calculated from the data in Table 16 and 17, resulting in 3.1 $kg \cdot m^{-2}$ for both depths. The proportion of buffer area with the correct canopy height was then applied against the value of in 3.1 $kg \cdot m^{-2}$ to estimate a standing stock (Table 18). Not surprisingly, the highest estimated standing stocks for *Saccharina* occurred in Zone 6 with moderate amounts at 5 m depth in Zones 1 and 4 (Table 18).

DISCUSSION

Algal communities in the survey area

The abundance and diversity of algae observed in the study area was strongly related to the depth, diversity and abundance of bottom types in each zone. Zones 1 – 3 were relatively shallow and sheltered and were dominated by soft mud / silt (towfish data, Table 5). Towfish data also indicated over 80% of the bottom in these zones had no consistent macrophyte cover (Table 6). The echosounder data (Table 10) are consistent with the towfish data in this regard. The echosounder data were stratified by depth and indicated that of the three zones, only Zone 1 had moderate amounts of hard substrata and these only occurred in relative abundance at the 5 m depth contour. Zone 1 at 5 m depth was also the only location in these three zones with a relative abundance of taller canopy (Table 14), indicating kelps. Zone 4 was similar to the first three zones in terms

of its shallow depths but it had slightly more hard substrate (Table 5). All four of these relatively shallow protected zones had limited algal or seagrass cover, usually less than 10% each of *Fucus*, *Saccharina* or *Zostera* dominated cover in the towfish transects (Table 6). Zone 4 also had small amounts of *Agarum* and *Desmarestia* (Table 6).

Zone 5 was a transitional area, deeper and with a greater variety of bottom types relative to the first four zones (towfish data, Table 5). Zone 5 also had the most even proportions of all canopy types and was the only zone not missing any canopy types (Table 6). This zone had the highest proportion of *Saccharina* dominated canopy at 30% (towfish data, Table 6). The echosounder data indicated that Zone 5 was also dominated by hard substrata at 5 m and 10 m depth (Table 10). Zone 5 also consistently had a detectable algal canopy of over 50% of classified VH data points at 5 and 10 m (Table 14). Of the first five zones only Zone 1 at 5 m depth had similar algal cover (Table 14).

Zone 6 was the deepest and most exposed of all zones, with no soft bottoms recorded by the towfish (Table 5). Consistent with the greater depths of Zone 6, there was a considerable amount of completely or partially bare bottom and the dominant alga was *Agarum* (towfish data, Table 6). The echosounder data confirmed the very high proportion of hard bottom at all depths in Zone 6 (Table 10). Zone 6 had the highest proportion of detectable canopy in the VH analysis, with 80% or more of data points at 5 and 10 m indicating algal cover and over 50% algal cover even at 20 m (Table 14). A relatively high proportion of these data points at 5 and 10 m were for a canopy height of ≥ 0.5 m, indicating kelps.

Previous algal surveys in the study area

The study area was impacted by the "Arrow" Bunker C fuel oil spill of February 4, 1970 (Levy 1972). A survey of algae was made in the area approximately one month after the event, but no major effects were observed at the time (Craigie and McLachlan 1970). The observations were qualitative and limited but do match the species and distributions that we found. Thomas (1978) demonstrated that *A. nodosum*, *C. crispus* and *F. vesiculosus* could have significantly lower biomass at oiled locations in the area, at least over the short term. After approximately three years much of the oiled shoreline had cleared naturally, but the upper intertidal zone of Rabbit Island was still covered in a stiff oil and sediment mixture six years later with spotty oiling still evident in portions of Lennox Passage (Keizer et al. 1978). In some sites, relatively unweathered oil deposits still persisted even twenty years later (Vandermeulen and Singh 1994). Although we were not specifically looking for remnants of the oil spill in our survey, nothing obvious or untoward was observed.

Moore et al. (1986) ran several SCUBA transects within our survey area. One was located just to the west of T1 at the west end of Rabbit Island. They recorded *Fucus* in the shallows, with a mix of *Saccharina* and *Chondrus* on boulders to a depth of approximately 10 m, and *Agarum* at 10 to 12 m with a softer bottom at 12 to 15 m. Their transect #36 in St. Peters Bay was located just to the north of T11. Here they found *Fucus* in the shallows again, with *Fucus*, *Saccharina* and *Laminaria* mixed on cobble and gravel to a depth of approximately 10 m. From 10 to 15 m, scattered boulders on

gravel and mud began to predominate along with some filamentous algae. These observations are consistent with our survey, and indicate that the structure and zonation of the algal community had changed little in those two areas since 1984/85 - a span of 25 years. However, one of the Moore et al. (1986) transects, #37, (just east of T14) appears to be anomalous to our findings. They discovered *Fucus*, *Saccharina* and *Laminaria* on boulders in the shallows, and *Saccharina*, *Laminaria* and filamentous algae on boulders in gravel and sand at 8 m. In our survey, T14 was dominated by 70% bare or 100% bare bottom classes down to 10 m depth. This may have been due to the predominantly sandy bottom we found below 5 m depth on T14, with perhaps a recent grazing or storm event removing algal cover in the shallows. T14 is situated in a very exposed small bay.

Novaczek and McLachlan (1989) provide a comprehensive assessment of different shore zones in Nova Scotia and associated algal floras. Our survey area falls within their Eastern Atlantic Sector designation and their detailed taxonomic list for this sector includes the more limited subset of genera which we observed. One of their sampling stations was located at the eastern end of Isle Madame in Rocky Bay, just outside of our survey area. The vertical distribution of algal taxa they found at that station is consistent with our own general observations for the survey area.

Commercial implications of the survey

The main purpose of our survey was to examine algal cover and biomass in subtidal areas in southwest Cape Breton for potential commercial exploitation. Based upon echosounder and towfish data, the most promising areas appear to be Zone 1 at 5 m depth and Zones 5 & 6 at 5 and 10 m depth. The destructive samples associated with these areas (2-5-2, 11-10-2, 12-5-2, 13-10-1, and 14-5-4) provide some information on algal standing stocks at those two depths (Tables 16 and 17).

Rather than guessing at what a commercially viable algal biomass might be, we chose to screen the biomass data in those samples by an amount which might indicate that the algal species in question was a permanent, rather than ephemeral, member of the algal community. Based upon experience, we chose a wet weight of 50 $g \cdot m^{-2}$ to indicate an algal population that might be reliably found in the areas year after year. Algae with a wet weight of over 50 $g \cdot m^{-2}$ at 5 m in these areas can include *C. crispus*, *C. purpureum*, *Desmarestia* spp., *F. serratus*, *F. lumbricalis*, *Phyllophora* sp., *Polysiphonia* spp. and *S. latissima*. *Fucus serratus* and *S. latissima* dominated in the 5 m samples with wet weights sometimes over 1000 $g \cdot m^{-2}$. Algae with a wet weight of over 50 $g \cdot m^{-2}$ at 10 m in these areas can include *Antithamnionella* sp., *Corallina* sp., *C. purpureum, Desmarestia* spp., *F. vesiculosus*, *Gracilaria* sp., *Polysiphonia* spp. and *S. latissima*. *Desmarestia* spp. and *S. latissima* dominated in the 10 m samples with wet weights sometimes over 1000 $g \cdot m^{-2}$.

Of the algal genera listed above, only *Chondrus, Fucus, Gracilaria* and *Saccharina* have a history of traditional commercial exploitation – and only *Fucus* and *Saccharina* had relatively high biomass in the survey. However, the other subtidal algal genera enumerated in this survey may eventually have commercial value as novel uses for them are discovered (therapeutants, bio-active compounds, etc.; see Cornish and

Garbary 2010, Cornish et al. 2015). For example, a biopolymer in *C. purpureum* is known to agglutinate mouse leukemia cells (Kamiya et al. 1980), and this species plus the genera *Phyllophora* and *Polysiphonia* can contain phenylethlamine alkaloids of interest in pharmacology (Güven et al. 2010). Novel uses for marine algae have been studied at the Halifax National Research Council laboratories for some time and they were interested in the results of this survey (Shawna MacKinnon pers. comm.).

Traditionally, the primary subtidal harvest in Nova Scotia has been for kelps, although it has always been quite limited (Vandermeulen 2013a). The high priority areas mentioned above (Zone 1 at 5 m; Zones 5 & 6 at 5 and 10 m) also had higher than normal estimated standing stocks of *S. latissima* (Table 18). A higher potential biomass was also estimated for Zone 4 at 5 m (Table 18). The standing stock estimates for *S. latissima* provided by our study can be of use for harvest planning.

Three of the survey genera have a history of intertidal commercial exploitation in Nova Scotia, *Ascophyllum*, *Chondrus* and *Palmaria*. The first two genera are traditionally harvested in the intertidal via skiffs and long handled rakes (Vandermeulen 2013a). *Palmaria* is hand-picked at low tide. Since our shoreline survey was limited to only three sites within Zone 4 and one site in Zone 2, it is not possible to draw reliable conclusions on intertidal standing stocks. *Chondrus* and *Palmaria* were not found at the shore stations, although they did occur at 5 and 10 m (beyond the range of a traditional harvest).

However, the biomass seen on shore for *A. nodosum* was encouraging, averaging approximately 6 $kg \cdot m^{-2}$ wet weight from our three samples. The value is at the low end of those seen in the more traditionally harvested areas of southwest Nova Scotia (Vandermeulen 2013a), but still encouraging from a commercial perspective. The peak biomass seen at station 7-S (14 $kg \cdot m^{-2}$ wet weight) is well within the high end of biomass seen in the traditional harvest areas. A more detailed assessment of the *Ascophyllum* standing stock for commercial purposes is warranted in Lennox Passage.

The value of nested acoustic methods for assessing algal populations

One of the fundamental limitations of vessel based benthic habitat survey methods is equipment operating depths. Our vessel and hardware (both towfish and echosounder) can operate in < 1 m of water. This is very shallow for a sidescan, but consistent with other macrophyte based echosounder surveys (e.g. Duarte 1987; Leisti et al. 2006; Istvánovics et al. 2008; Herbst et al. 2013). Our depth maximum was 30 m, due to the pressure rating of the sidescan case. This operating range, essentially surface to 30 m, is adequate to capture algal populations in their normal depth ranges in Atlantic Canada.

There is a more specific limitation on the ability of an echosounder to detect a macrophyte canopy. After several decades of research on this topic, the general consensus is that narrow beam (≤ 6°) transducers running at ≥ 200 kHz appear to work best (e.g. Thomas et al. 1990) and most macrophyte studies now utilize transducers with similar specifications (Marbà et al. 2002; Sabol et al. 2002; Tegowski et al. 2003; Leisti et al. 2006; Winfield et al. 2007; Istvánovics et al. 2008; Chamberlain et al. 2009;

Sabol et al. 2009; Valley et al. 2010; Stevens and Lacy 2012; Herbst et al. 2013). Our macrophyte transducer ran at 430 kHz with a 6° cone angle.

The detection limit, the point of rare false positive canopy identification by echosounder software, was 20 cm in our survey. A detection limit of approximately 10 – 20 cm is common in other macrophyte studies (Duarte 1987; Sabol et al. 2002; Chamberlain et al. 2009; Sabol et al. 2009; Abukawa et al. 2013).

Detection limits aside, it is still possible for echosounder software to incorrectly classify algal habitat as something else. Anderson et al. (2002) used an echosounder running QTC VIEW software to discern macroalgae on rock in the coastal waters of Newfoundland. There were issues with false positive QTC classifications of rock / macroalgae at depths >50 m, where the macrophytes were known not to occur. Post processing involving binning the results by depth and relief improved the accuracy of the classifications. Jordan et al. (2005) also binned echosounder data by depth strata from the surface to approximately 45 m to aid their macrophyte classifications. We tried to avoid misclassifications via our novel nested sampling technique, carefully ground truthing our data at each sampling scale and depth.

The towfish video with approximately 1 m width of view was used to ground-truth the sidescan imagery which operated at the next higher observational scale, the 30 m swath width. The towfish classifications of canopy and bottom types were then used to ground truth the highest survey scale, the echosounder data. To our knowledge, the only other survey to employ video, sidescan and echosounder to detect macrophytes was Hewitt et al. (2004), although with a different survey design and without transponder positioning. They used sidescan sonar to completely survey the relatively soft bottom of several 1 km^2 target areas at 10 – 20 m depth in Kawau Bay, New Zealand; and then ran discrete echosounder and towed video camera transects through a portion of each area. The echosounder data were analysed with QTC VIEW software. Seaweeds were not the major focus of their study, although they did record kelp and coralline algae in their video classifications with no further taxonomic specifications.

Our video and acoustic methods did provide algal information of interest for harvest purposes. It was possible to identify areas with bottom types conducive to the presence of algae, and to locate algal canopies within these areas. This was proven conclusively at sample site B-2, where echosounder imagery suggested very large thalli of *S. latissima* and subsequent destructive sampling at the site confirmed the presence of these thalli and their high biomass (14 $kg \cdot m^{-2}$ wet weight, Table 16).

The three field trips comprised a total of 12 days on the water, handled by a crew of three on one small vessel. The surface area covered by the survey was approximately 140 km^2 – about 12 km^2 per day. The survey was very cost effective in covering such a large area. However, the sampling 'grid', comprised of widely spaced towfish transects subsequently crossed by echosounder paths at 5, 10 and 20 m, was quite coarse. Ultimately, this lead to a relatively high proportion of unclassified VH data points in the GIS (often > 20% and sometimes > 50%, Table 10) due to the relative paucity of echosounder ground truth crosses with the towfish transects. The addition of more towfish transects could have improved the accuracy of our spatial analysis, but with a

greater field cost. The survey did not produce spatially detailed information, but it did provide adequate information for focussing further exploration for commercial purposes.

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Table 1. Species list.

Taxon	Name used in text
Agarum Dumortier	*Agarum*
Agarum clathratum Dumortier	*A. clathratum*
Ahnfeltia Fries	*Ahnfeltia*
Antithamnionella Lyle	*Antithamnionella*
Ascophyllum Stackhouse	*Ascophyllum*
Ascophyllum nodosum (L.) Le Jolis	*A. nodosum*
Bonnemaisonia hamifera Hariot	*B. hamifera*
Callithamnion Lyngbye	*Callithamnion*
Callophyllis cristata (C. Agardh) Kützing	*C. cristata*
Ceramium Roth	*Ceramium*
Ceramium virgatum Roth	*C. virgatum*
Chondrus crispus Stackhouse	*C. crispus*
Chorda Stackhouse	*Chorda*
Chordaria C.Agardh	*Chordaria*
Corallina L.	*Corallina*
Cystoclonium purpureum (Hudson) Batters	*C. purpureum*
Desmarestia J.V. Lamouroux	*Desmarestia*
Desmarestia aculeata (L.) J.V. Lamouroux	*D. aculeata*
Desmarestia viridis (O.F. Müller) J.V. Lamouroux	*D. viridis*
Dictyosiphon Greville	*Dictyosiphon*
Dilsea integra (Kjellman) Rosenvinge	*D. integra*
Ectocarpus Lyngbye	*Ectocarpus*
Fucus L.	*Fucus*
Fucus distichus L.	*F. distichus*
Fucus serratus L.	*F. serratus*
Fucus vesiculosus L.	*F. vesiculosus*
Furcellaria lumbricalis (Hudson) J.V. Lamouroux	*F. lumbricalis*

Gracilaria Greville	*Gracilaria*
Halosiphon Jaasund	*Halosiphon*
Laminaria digitata (Hudson) J.V. Lamouroux	*L. digitata*
Neosiphonia harveyi (J.W. Bailey) M.-S. Kim, H.-G. Choi, M. Guiry & G.W. Saunders	*N. harveyi*
Odonthalia dentata (L.) Lyngbye	*O. dentata*
Palmaria palmata (L.) Weber & Mohr	*P. palmata*
Phycodrys rubens (L.) Batters	*P. rubens*
Phyllophora Greville	*Phyllophora*
Polysiphonia Greville *Polysiphonia fucoides* (Hudson) Greville	*Polysiphonia* *P. fucoides*
Ptilota C. Agardh *Ptilota serrata* Kützing	*Ptilota* *P. serrata*
Rhodomela C.Agardh *Rhodomela confervoides* (Hudson) P.C. Silva	*Rhodomela* *R. confervoides*
Saccharina Stackhouse *Saccharina groenlandica* (Rosenvinge) C.E. Lane, C. Mayes, L. Druehl & G.W. Saunders *Saccharina latissima* (L.) C.E. Lane, C. Mayes, L. Druehl & G.W. Saunders	*Saccharina* *S. groenlandica* *S. latissima*
Sphacelaria Lyngbye in Hornemann, 1818	*Sphacelaria*
Zostera L. *Zostera marina* L.	*Zostera* *Z. marina*

Table 2. Towfish bottom classification codes.

Code	Type
1	soft (mud / silt)
2	hard (sand / silt)
3	hard (coarse gravel with occasional cobble)
4	hard (cobble on sand base)
5	hard (boulder / reef)

Table 3. Towfish canopy classification codes.

Code	Type
1	*Fucus* dominant (cover ≥ 50%) - mostly *F. serratus*; may have some *Chorda / Halosiphon*, *Saccharina*, red algal turf or bare patches; *Zostera* cover can be up to 50% at some shallow locations
2	*Saccharina* dominant (cover ≥ 50%) – mostly crozier morph of *S. latissima* (T13 had *L. digitata* mixed in); may have some *Fucus*, *Agarum*, *Desmarestia*, red algal turf or bare patches
3	*Zostera* dominant (cover ≥ 50% as a 'meadow', more extensive than a collection of patches) – may have some *Fucus*, *Chorda / Halosiphon*, variety of other seaweeds, or bare patches
4	*Agarum* dominant (cover ≥ 40%) – usually in deeper areas with many bare patches, may have some *Saccharina*, *Desmarestia* or red algal turf (*Ptilota*)
5	70% bare – may have some algal turf (green, brown or red), *Zostera*, *Chorda / Halosiphon*, *Saccharina*, *Desmarestia*, *Agarum*, or drift material
6	100% bare – no consistent macrophyte cover; may have some algal mats, organic debris, or drift material
7	*Desmarestia* dominant (cover ≥ 50%) – may have some *Saccharina*, *Agarum*, bare patches or drift material
8	red algal coralline crust on boulders at depth (cover ≥ 50%) – may have some *Agarum*, *Desmarestia*, or sea urchins; upright coralline thalli rare

Table 4. Sample towfish ground truth data[a].

GTP	Z	T	Year	M	D	H	Mi	S	Depth (m)	Target LAT	Target LONG	Decimal LAT	Decimal LONG	BC	CC
1	1	1	2010	6	10	7	42	0	1.91	4532.641363	-6111.715507	45.54402272	-61.19525845	3	1
2	1	1	2010	6	10	7	42	2	2.25	4532.641542	-6111.715096	45.5440257	-61.1952516	3	1
3	1	1	2010	6	10	7	42	4	2.52	4532.642041	-6111.714337	45.54403402	-61.19523895	3	1
4	1	1	2010	6	10	7	42	5	2.79	4532.64267	-6111.713684	45.5440445	-61.19522807	3	1
5	1	1	2010	6	10	7	42	7	2.91	4532.642973	-6111.713383	45.54404955	-61.19522305	3	1
...															
22911	6	16	2010	6	8	8	53	40	19.87	4534.395571	-6046.862547	45.57325952	-60.78104245	3	4
22912	6	16	2010	6	8	8	53	42	21.44	4534.393346	-6046.865268	45.57322243	-60.7810878	3	4
22913	6	16	2010	6	8	8	53	43	20.33	4534.394834	-6046.864651	45.57324723	-60.78107752	3	4

22914	6	16	2010	6	8	8	53	45	21.15	4534.393609	-6046.863355	45.57322682	-60.78105592	3	4
22915	6	16	2010	6	8	8	53	46	20.88	4534.392867	-6046.864342	45.57321445	-60.78107237	3	4

[a]GTP = ground truth point record number, Z = zone, T = transect, M = month, D = day, H = hour, Mi = minute, S = second, BC = bottom type code, CC = canopy code

Table 5. Towfish bottom type data by zone.

Zone	Count for bottom type #1 (%)	Count for bottom type #2 (%)	Count for bottom type #3 (%)	Count for bottom type #4 (%)	Count for bottom type #5 (%)	Total by zone
1	2910 (76.5)	38 (1.0)	750 (19.7)	106 (2.8)	0 (0.0)	3804
2	1921 (76.3)	0 (0.0)	596 (23.7)	0 (0.0)	0 (0.0)	2517
3	2205 (99.5)	0 (0.0)	11 (0.5)	0 (0.0)	0 (0.0)	2216
4	3715 (61.5)	236 (3.9)	2010 (33.3)	79 (1.3)	0 (0.0)	6040
5	1201 (21.6)	877 (15.8)	2213 (39.8)	0 (0.0)	1264 (22.8)	5555
6	0 (0.0)	943 (33.9)	1350 (48.5)	150 (5.4)	340 (12.2)	2783
Totals	11952	2094	6930	335	1604	22915

Table 6. Towfish canopy type data by zone.

Zone	Count for canopy type #1 (%)	Count for canopy type #2 (%)	Count for canopy type #3 (%)	Count for canopy type #4 (%)	Count for canopy type #5 (%)	Count for canopy type #6 (%)	Count for canopy type #7 (%)	Count for canopy type #8 (%)	Total by zone
1	204 (5.4)	212 (5.6)	32 (0.8)	0 (0.0)	217 (5.7)	3139 (82.5)	0 (0.0)	0 (0.0)	3804
2	43 (1.7)	162 (6.4)	33 (1.3)	0 (0.0)	123 (4.9)	2156 (85.7)	0 (0.0)	0 (0.0)	2517
3	11 (0.5)	0 (0.0)	57 (2.6)	0 (0.0)	0 (0.0)	2148 (97.0)	0 (0.0)	0 (0.0)	2216
4	283 (4.7)	856 (14.2)	226 (3.7)	11 (0.2)	216 (3.6)	4263 (70.6)	185 (3.1)	0 (0.0)	6040
5	970 (17.5)	1666 (30.0)	257 (4.6)	38 (0.7)	116 (2.1)	2073 (37.3)	152 (2.7)	283 (5.1)	5555
6	0 (0.0)	34 (1.2)	0 (0.0)	976 (35.1)	562 (20.2)	1211 (43.5)	0 (0.0)	0 (0.0)	2783
Totals	1511	2930	605	1025	1234	14990	337	283	22915

Table 7. 5m bottom type cross points –comparisons between towfish and VH analysis.

Cross point	Towfish class	VH class 1	VH class 2	VH class 3	VH class 4	VH class 5	VH class 6	VH total count
T3 north	1 - soft	7	1	0	0	0	0	8
T4 north	1 - soft	8	1	0	0	0	0	9
T4 south[a]	1 - soft	3	5	0	0	0	0	8
T5 north	1 - soft	9	0	0	0	0	0	9
T5 south	1 - soft	9	0	0	0	0	0	9
T6 north	1 - soft	8	0	0	0	0	0	8
T6 south[a]	1 - soft	5	3	0	0	0	0	8
T7 south	1 - soft	75	14	0	0	0	0	89
T8 north	1 - soft	6	3	0	0	0	0	9
T8 south	1 - soft	8	1	0	0	0	0	9
T1 north	3 - coarse gravel	0	3	0	3	4	0	10
T2 north	3 - coarse gravel	1	2	0	6	0	0	9
T2 south	3 - coarse gravel	0	4	1	2	1	0	8
T3 middle north	3 - coarse gravel	0	1	0	6	2	0	9
T3 middle south	3 - coarse gravel	0	1	0	5	4	0	10
T3 south	3 - coarse gravel	2	2	1	4	0	0	9
T7 north	3 - coarse gravel	3	5	1	0	0	0	9
T7 middle north	3 - coarse gravel	1	2	1	6	0	0	10
T7 middle south	3 - coarse gravel	1	2	0	6	0	0	9

T9	3 - coarse gravel	0	0	0	2	6	1	9
T10 north	3 - coarse gravel	1	1	2	5	0	0	9
T10 middle	3 - coarse gravel	0	0	0	6	4	0	10
T10 south - N	3 - coarse gravel	0	0	0	10	3	0	13
T10 south - S	3 - coarse gravel	0	0	0	0	11	0	11
T11	3 - coarse gravel	0	1	2	6	2	0	11
T12 north	3 - coarse gravel	0	2	0	3	4	0	9
T12 south - N	3 - coarse gravel	1	4	0	4	1	0	10
T12 south - S	3 - coarse gravel	2	2	5	0	0	0	9
T14 north	3 - coarse gravel	0	0	4	7	0	0	11
T14 middle	3 - coarse gravel	0	0	1	10	20	0	31
T1 south	4 – cobble on sand	0	1	6	1	0	0	8
T13[b]	5 - boulder / reef	0	4	2	2	0	0	8

[a] this cross is a transitional area, soft but just before firmer zone

[b] this cross is a transitional area, reef just before flat sand / silt

Table 8. 10m bottom type cross points –comparisons between towfish and VH analysis.

Cross point	Towfish class	VH class 1	VH class 2	VH class 3	VH class 4	VH class 5	VH class 6	VH total count
T1 south	1 - soft	0	0	0	0	8	0	8
T2 north[a]	1 - soft	0	0	1	1	5	0	7
T2 south - N	1 - soft	0	0	0	0	3	4	7
T2 south - S	1 - soft	0	0	0	0	3	6	9
T6 north	1 - soft	0	0	0	0	2	8	10
T6 south	1 - soft	0	0	0	0	3	4	7
T8 north	1 - soft	0	0	0	0	3	5	8
T8 middle	1 - soft	0	0	0	0	2	3	5
T8 south	1 - soft	0	0	0	0	3	5	8
T10	1 - soft	0	0	0	0	7	0	7
T12 north	1 - soft	0	0	0	0	9	11	20
T7 south	2 - sand / silt	0	0	3	4	0	0	7
T13	2 - sand / silt	0	1	0	2	4	0	7
T14	2 - sand / silt	0	0	1	0	7	0	8
T1 north	3 - coarse gravel	0	0	0	3	3	0	6
T2 middle[a]	3 - coarse gravel	0	1	1	1	5	0	8
T7 north	3 - coarse gravel	0	0	3	4	1	0	8
T9	3 - coarse gravel	0	0	5	4	1	0	10
T11	3 - coarse gravel	0	2	3	1	1	0	7

T12 south	3 - coarse gravel	0	0	5	4	3	0	12

[a] transition area, right by harder bottom

Table 9. 20m bottom type cross points –comparisons between towfish and VH analysis.

Cross point	Towfish class	VH class 1	VH class 2	VH class 3	VH class 4	VH class 5	VH class 6	VH total count
T8 north	1 - soft	3	1	0	0	0	0	4
T8 south	1 - soft	5	1	0	0	0	0	6
T10	1 - soft	4	0	0	0	0	0	4
T9	2 - sand / silt	4	0	3	0	0	0	7
T15	2 - sand / silt	3	0	1	0	0	0	4
T11	3 - coarse gravel	0	0	2	5	0	0	7
T16	3 - coarse gravel	0	2	1	1	0	0	4

Table 10. Summary VH bottom type classification by zone and depth (GIS points color coded clear, red and blue).

Zone	depth	clear	red	blue	total	% clear	% red	% blue	total %	Blue : red
1	5	966	522	2089	3577	27.00587	14.59323	58.40089	100	4.001916
2	5	1368	1755	1546	4669	29.29964	37.58835	33.11202	100	0.880912
3	5	780	1577	554	2911	26.79492	54.17382	19.03126	100	0.3513
4	5	2358	3016	3536	8910	26.46465	33.84961	39.68575	100	1.172414
5	5	1746	886	4280	6912	25.26042	12.81829	61.9213	100	4.8307
6	5	602	90	3291	3983	15.11424	2.259603	82.62616	100	36.56667
1	10	1681	853	451	2985	56.31491	28.57621	15.10888	100	0.528722
2	10	45	39	1	85	52.94118	45.88235	1.176471	100	0.025641
3	10	168	332	325	825	20.36364	40.24242	39.39394	100	0.978916
4	10	1007	1129	1338	3474	28.98676	32.49856	38.51468	100	1.18512
5	10	1803	320	3791	5914	30.48698	5.410889	64.10213	100	11.84688
6	10	477	30	2514	3021	15.78947	0.993049	83.21748	100	83.8
4	20	87	641	104	832	10.45673	77.04327	12.5	100	0.162246
5	20	210	428	670	1308	16.05505	32.72171	51.22324	100	1.565421
6	20	861	129	1406	2396	35.93489	5.383973	58.68114	100	10.89922

Table 11. 5m canopy type cross points –comparisons between towfish and VH analysis.

Cross point	Towfish class	VH canopy 0 - <0.2m	VH canopy 0.2 - <0.5m	VH canopy 0.5 - 3m	VH total count	VH canopy point matches video right at the cross point?
T11	1 - *Fucus*	0	11	0	11	yes, quite a bit of *Saccharina* mixed in so taller canopy
T12 north	1 - *Fucus*	6	2	0	8	yes, *Fucus* on scattered cobble on sand, no *Saccharina* so shorter canopy
T13[a]	1 - *Fucus*	1	7	1	9	yes, quite a bit of *Saccharina* mixed in so taller canopy
T1 north[b]	2 - *Saccharina*	4	6	0	10	yes, low (along bottom) plants right at this edge, taller just a bit farther up
T1 south	2 - *Saccharina*	0	8	0	8	yes, in dense bed of mainly crozier morph
T3 middle north	2 - *Saccharina*	0	9	0	9	yes, in dense bed of mainly crozier morph
T7 north	2 - *Saccharina*	1	6	2	9	yes, mainly crozier morph, some quite tall, but bare areas too
T10 north	2 - *Saccharina*	0	8	1	9	yes, in dense bed of mainly crozier morph
T12 south	3 - *Zostera*	0	10	0	10	yes, no direct cross but closest video shows sparse short eelgrass with some *Saccharina*
T2 north	5 - 70% bare	6	2	0	8	yes, mainly bare bottom with some filamentous tufts of red or brown algae
T3 middle south	5 - 70% bare	5	5	0	10	yes, mainly bare but some patches of *Saccharina* with crozier morph

T7 middle south	5 - 70% bare	1	8	0	9	yes, mainly bare but some patches of *Saccharina* with crozier morph
T9	5 - 70% bare	5	4	0	9	yes, mainly bare but some patches of *Saccharina*
T12 middle	5 - 70% bare	7	3	0	10	yes, mainly bare but some patches of *Saccharina* with crozier morph
T14 north	5 - 70% bare	6	4	0	10	yes, mainly bare but some patches of *Saccharina* with crozier morph
T14 south[c]	5 - 70% bare	7	24	0	31	yes, no direct cross but closest video shows mainly bare with some patches of *Desmarestia* and *Saccharina*
T2 south[d]	6 - 100% bare	6	2	0	8	yes, bare with a few filamentous tufts of red or brown algae
T3 north	6 - 100% bare	8	0	0	8	yes, bare bottom with no algal thalli
T3 south	6 - 100% bare	9	0	0	9	yes, bare bottom with no algal thalli
T4 north	6 - 100% bare	8	1	0	9	yes, bare bottom with no algal thalli
T4 south	6 - 100% bare	8	0	0	8	yes, bare bottom with no algal thalli
T5 north	6 - 100% bare	9	0	0	9	yes, bare bottom with no algal thalli
T5 south	6 - 100% bare	9	0	0	9	yes, bare bottom with no algal thalli
T6 north	6 - 100% bare	8	0	0	8	yes, bare bottom with no algal thalli
T6 south	6 - 100% bare	8	0	0	8	yes, bare bottom with no algal thalli
T7 middle north	6 - 100% bare	7	3	0	10	yes, bare with a few filamentous tufts of red or brown algae
T7 south	6 - 100% bare	84	3	2	89	yes, bare with a few drift thalli of *Saccharina* or *Fucus* - not a true cross point but a long run of VH points parallel to or crossing the towfish track
T8 north	6 - 100% bare	9	0	0	9	yes, bare and no distinct algal thalli seen

T8 south	6 - 100% bare	7	2	0	9	yes, bare with some drift thalli (indeterminate)
T10 middle	6 - 100% bare	8	2	0	10	yes, bare with a few drift thalli of *Saccharina*
T10 south - N	6 - 100% bare	12	1	0	13	yes, bare with a few drift thalli of *Saccharina*
T10 south - S	6 - 100% bare	9	2	0	11	yes, bare with a few thalli of *Chorda / Halosiphon*

[a] near transition point with class 6 - 100% bare

[b] right at transition point with class 6 - 100% bare

[c] south end of this oblique hit transitions to class 6 - 100% bare

[d] near transition point with class 5 - 70% bare

Table 12. 10m canopy type cross points –comparisons between towfish and VH analysis.

Cross point	Towfish class	VH canopy 0 - <0.2m	VH canopy 0.2 - <0.5m	VH canopy 0.5 - 1.6m	VH total count	VH canopy point matches video right at the cross point?
T7 north	2 - *Saccharina*	0	6	2	8	yes, moderately dense tall *Saccharina* of crozier morph
T11	2 - *Saccharina*	0	5	2	7	yes, moderately dense tall *Saccharina* of crozier morph
T12 south	2 - *Saccharina*	2	9	0	11	yes, moderately dense tall *Saccharina* of crozier morph
T2 middle[a]	5 - 70% bare	8	0	0	8	yes, bare bottom with rare single thalli of *Saccharina*
T9[b]	5 - 70% bare	2	8	0	10	partially, low density *Agarum*, *Saccharina* and turf algae
T1 north	6 - 100% bare	6	4	0	10	yes, bare bottom with short scruffy turf / debris
T1 south	6 - 100% bare	9	0	0	9	yes, bare bottom with no algal thalli
T2 north	6 - 100% bare	5	2	0	7	yes, bare bottom with no algal thalli
T2 south - N	6 - 100% bare	7	0	0	7	yes, bare bottom with no algal thalli
T2 south - S	6 - 100% bare	9	0	0	9	yes, bare bottom with no algal thalli
T6 north	6 - 100% bare	10	0	0	10	yes, bare bottom with no algal thalli
T6 south	6 - 100% bare	7	0	0	7	yes, bare bottom with no algal thalli
T7 south[c]	6 - 100% bare	0	7	0	7	partially, scattered tall sponge on softer bottom, no algal material
T8 north	6 - 100% bare	6	2	0	8	yes, bare bottom with short scruffy turf / debris

T8 middle[d]	6 - 100% bare	5	0	0	5	yes, bare bottom with no algal thalli
T8 south	6 - 100% bare	7	1	0	8	yes, bare bottom with no algal thalli
T10	6 - 100% bare	6	1	0	7	partially, bare bottom with rare single thalli of *Saccharina*
T12 north[e]	6 - 100% bare	20	0	0	20	yes, bare bottom over about 10 VH points along towfish video track
T13	6 - 100% bare	8	0	0	8	yes, bare bottom with ripples
T14	6 - 100% bare	8	0	0	8	yes, bare bottom with ripples and some algal debris

[a] right at transition point with class 6 - 100% bare

[b] diagonal cross, several VH points into zone of towfish class 2 – *Saccharina*

[c] odd to see a canopy signal here, VH points just to west of this cross are all <0.2m

[d] not a complete cross, lost BioSonics data just to the east of the towfish track

[e] diagonal cross

Table 13. 20m canopy type cross points –comparisons between towfish and VH analysis.

Cross point	Towfish class	VH canopy 0 - <0.2m	VH canopy 0.2 - <0.5m	VH canopy 0.5 - 2.1m	VH total count	VH canopy point matches video right at the cross point?
T11	4 - *Agarum*	0	7	0	7	yes, moderately dense *Agarum*
T16[a]	4 - *Agarum*	4	0	0	4	partially, scattered *Agarum*, up to 70% bare bottom
T8 north	6 - 100% bare	4	0	0	4	yes, bare bottom with no algal thalli
T8 south	6 - 100% bare	6	0	0	6	yes, bare bottom with no algal thalli
T9	6 - 100% bare	4	3	0	7	partially, some scattered thalli of *Saccharina* and *Agarum*
T10	6 - 100% bare	4	0	0	4	yes, bare bottom with no algal thalli
T15	6 - 100% bare	4	0	0	4	yes, bare bottom with sand ripples

[a] some scattered VH dots with canopy 0.2 to 0.5 m just outside of transect

Table 14. Final VH canopy type classification by zone and depth.

Zone	Depth	<0.2m	≥0.2 and <0.5m	≥0.5m	Total points	Tallest thallus (m)	% <0.2m	% ≥0.2 and <0.5m	% ≥0.5m
1	5	1377	1722	508	3607	1.46	38	48	14
2	5	4034	548	88	4670	1.11	86	12	2
3	5	2434	433	45	2912	0.85	83	15	2
4	5	5158	2966	787	8911	1.87	57	33	9
5	5	3239	3356	317	6912	1.44	46	49	5
6	5	527	2201	1255	3983	2.54	13	55	32
1	10	2602	370	12	2984	0.81	87	12	0.4
2	10	82	4	0	86	0.26	95	5	0
3	10	733	88	4	825	1.24	89	11	0.5
4	10	2222	1105	146	3473	1.58	64	32	4
5	10	2706	2999	210	5915	1.24	46	51	4
6	10	600	1596	825	3021	1.57	20	53	27
4	20	704	126	2	832	0.7	85	15	0.2
5	20	851	413	44	1308	2.05	65	32	3
6	20	1067	1166	163	2396	1.63	45	49	7

Table 15. Location and description of sampling stations.

ID #	Latitude Longitude	Depth (m)	Description	Sidescan Imagery	Video Record
4-S	45.567507 -61.111068	0	northwest shore of Bee Island	none	reference picture - rock / cobble beach with undercut trees showing shore erosion, *Ascophyllum*
7-S	45.599635 -61.006878	0	south shore of Birch Island	none	reference picture - very similar to 4-S, *Ascophyllum*
8-S	45.595026 -60.975970	0	northwestern shore of Bernard Island	none	reference picture - gently sloping cobble beach with no erosion, lack of *Ascophyllum*
9-S	45.593570 -60.946710	0	Gabion Point shore	none	reference picture - steeply sloping cobble / rock berm style beach, *Ascophyllum*
2-5-2	45.546967 -61.169482	4	small bay half way between Thomas Head and Strawberry Point, steeply sloping bottom rapidly dropping to 11 m	a highly reflective bottom with some texture	cobble bottom with red algae and some *Chorda / Halosiphon* and *Saccharina*
3-5-1	45.562360 -61.142816	6	off west side of Glasgow Point, western edge of shallow reef just before rapid drop off to 10 m	a highly reflective bottom with some texture	cobble bottom with red algae and large scattered *Saccharina*

B-2	45.609833 -61.003317	5	just north of Birch Island, eastern edge of shallow reef just before rapid drop off to 12 m	no sidescan for this site, echosounder data indicates large algae on a hard bottom	no video for this site
9-5-4	45.595136 -60.946269	3.5	just north of 9-S, middle of shallow reef	a highly reflective bottom with some texture	coarse gravel bottom with red algae, eelgrass, *Fucus* and *Saccharina* in an almost equal mix
10-5-2	45.618632 -60.949057	5	north side of Philip Rocks, shallow reef	a highly reflective bottom with some texture	coarse gravel / cobble bottom with extensive *Saccharina* and *L. digitata,* some patches of red algae
10-5-3	45.619192 -60.949343	6	80 m north of 10-5-2, on same shallow reef	a reflective bottom but slightly less hard than that in 10 – 5 – 2	coarse gravel bottom similar to 10 – 5 – 2 with extensive *Saccharina* and *L. digitata*; slightly fewer patches of red algae
12-5-2	45.645681 -60.891140	5	between Tillard Point and Pointe du Loup, gently sloping area of low relief	a highly reflective bottom with some texture	coarse gravel / cobble bottom with extensive cover of *Fucus,* some red algae, some bare areas and some *Saccharina*
14-5-4	45.607585 -60.799992	4	gently sloping bottom of low relief in bay just east of St. Peters Island	a highly reflective bottom with some texture	coarse gravel / cobble bottom with *F. serratus*, *Saccharina* and bare areas in equal amounts; some clumps of red algae, some *Desmarestia*
1-10-1	45.545210 -61.196067	9	north side of Thomas Head, edge of broad low relief area of 9-10m depth	a transition area of moderately reflective bottom fading to softer non-reflective sediments	silt covered gravel with extensive cover of *Saccharina*

				deeper	
2-10-1	45.553892 -61.172191	9	north of 2-5-2, edge of broad low relief area of 7-10 m depth	a highly reflective bottom with scattered large boulders, some approaching 1 m in diameter	silt covered gravel with occasional large rocks; *Saccharina* dominant with some clumps of red algae and some bare patches
7-10-1	45.598030 -61.006188	10	just south of 7-S, steeply sloping bottom into main channel	a transition area of moderate to low reflectivity, a soft channel bottom grading into a harder north side slope	silty but firm current swept bottom; grayish sponge *Haliclona* quite common; mainly bare sediment but some clumps of red algae and *Saccharina* on scattered rocks
11-10-2	45.612729 -60.896245	10	1 km west of Samson Rocks, on steeply sloping side of channel	a highly reflective bottom with scattered large boulders, some approaching 1 m in diameter	gravel / cobble bottom with *Saccharina* and some red algae plus bare patches; occasional *Desmarestia*
13-10-1	45.603369 -60.865024	8	southeastern side of Three Rocks reef	a highly reflective bottom with scattered large boulders, some approaching 1 m in diameter	gravel/cobble bottom with *Saccharina* and *Desmarestia* in equal measure; large clumps of red algae and bare areas
11-20-1	45.612200 -60.895753	20	70 m south of 11-10-2, on slope of same channel	a highly reflective bottom with scattered large boulders, some approaching 1 m in diameter; a highly reflective featureless zone just below this area	gravel/cobble bottom just above a sand flat area; *Agarum* dominates, with bare areas

13-20-1	45.608010 -60.861638	18	northeastern side of Three Rocks reef in channel 14-18 m deep	a highly reflective bottom with some texture	rough gravel covered in coralline red algal crust, not much seaweed; some *Agarum* and red algae; small amounts of *Desmarestia*

Table 16. Biomass data (wet weight $g \cdot m^{-2}$) for shore and 5 m sampling stations.

Taxon	Sampling Station ID#											
	4-S	7-S	8-S	9-S	2-5-2	3-5-1	B-2	9-5-4	10-5-2	10-5-3	12-5-2	14-5-4
Ahnfeltia										68		
A. nodosum	2200	14000		1900								
B. hamifera									200			
C. cristata									7.6	11		
Ceramium spp.[a]					31	26		23	390	2.7	6.4	43
C. crispus					44			56	11		130	87
Chordaria sp.								5.3				
Corallina sp.								73	9.3		95	
C. purpureum						5.8	25		21			80
Desmarestia spp.[b]			40							21		59
Dictyosiphon sp.					2.2							
D. integra										100		
Ectocarpus sp.					38							

F. distichus				200								
F. serratus	4200		360	200				3100		160	1800	2300
F. vesiculosus	670	3000	1600	4300								
F. lumbricalis					460	86		2.7	73	62	500	
L. digitata									2200	900		
P. palmata							27		270	6.7		5.3
P. rubens						20			22			
Phyllophora sp.					37	140	76	29	1100	410	100	92
Polysiphonia spp.[c]					42	14	160	630			110	4.0
Rhodomela sp.[d]								5.3	6.3	28		29
S. latissima[e]					2300	6700	14000	2.7	73	1200	500	80
Sphacelaria sp.					5.6							

[a]Most commonly *C. virgatum*, occasionally tangled in with small amounts of *Polysiphonia* spp., *Callithamnion* sp. or *B. hamifera*.

[b]An almost equal mix of *D. aculeata* and *D. viridis*, plus samples not identifiable to species.

[c]An almost equal mix of *P. fucoides* and *N. harveyi*, plus a few samples not identifiable to species.

[d]Most samples not identifiable to species, but a couple seen as *R. confervoides*

[e]An almost equal mix of the short stipe morph with frilly blade and the long stipe morph. B-2 with large long stipe plants with crozier morph and hyper-inflated stipe. Many of the plants under this taxon may actually be *S. groenlandica* (Saunders pers. comm.).

Table 17. Biomass data (wet weight $g \cdot m^{-2}$) for 10 and 20 m sampling stations.

Taxon	Sampling Station ID#						
	1-10-1	2-10-1	7-10-1	11-10-2	13-10-1	11-20-1	13-20-1
A. clathratum						3500	89
Antithamnionella sp.				69			
C. cristata	2.4	5.0					
Ceramium spp.	39	6.7			17		
C. crispus	160			4.0			
Chordaria sp.	16						
Corallina sp.					130		
C. purpureum		4.0	6.7	190			
Desmarestia spp.				93	1600	110	
D. integra						9.3	
Ectocarpus sp.		23					
F. vesiculosus					61		
F. lumbricalis	180	100					

Gracilaria sp.				130			
O. dentata						11	4.0
P. palmata	11	6.7	11	12			
P. rubens						36	12
Phyllophora sp.	96	68	4.0			15	5.3
Polysiphonia spp.	54	190	60	530			74
P. serrata						8.0	11
Rhodomela sp.	5.7			16	40		
S. latissima	4100	3400	950	4400	2700		

Table 18. *Saccharina* standing stock estimates based upon 40m wide buffer strips along 5 and 10 m depth VH classifications by Zone.

Zone - depth	Buffer area (km^2)	% of canopy[1] ≥0.5 m	Estimated standing stock (wet tonnes)
1 – 5m	0.5431	14	236
1 – 10m	0.5548	0.4	6.9
2 – 5m	0.7106	2	44
2 – 10m	0.01941	0	0
3 – 5m	0.4505	2	28
3 – 10m	0.146	0.5	2.3
4 – 5m	1.357	9	379
4 – 10m	0.6307	4	78
5 – 5m	1.047	5	162
5 – 10m	1.067	4	132
6 – 5m	0.6107	32	606
6 – 10m	0.5527	27	463

[1] From Table 14

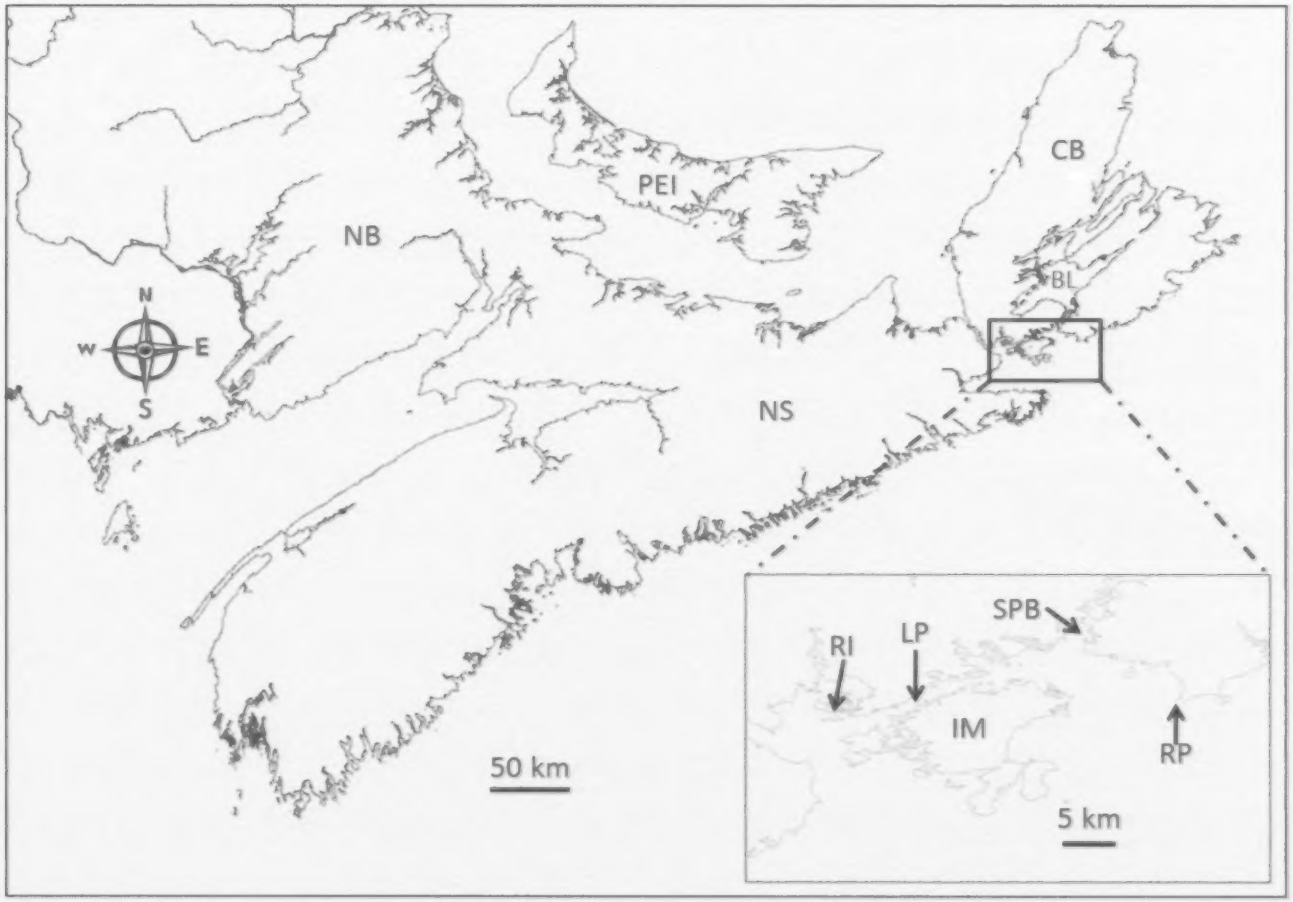

Figure 1: The study area. The provinces of New Brunswick (NB), Prince Edward Island (PEI), and Nova Scotia (NS) with its Cape Breton region (CB) including Bras d'Or Lake (BL). Inset: Ilse Madame (IM), Rabbit Island (RI), Lennox Passage (LP), St. Peters Bay (SPB), and Red Point (RP).

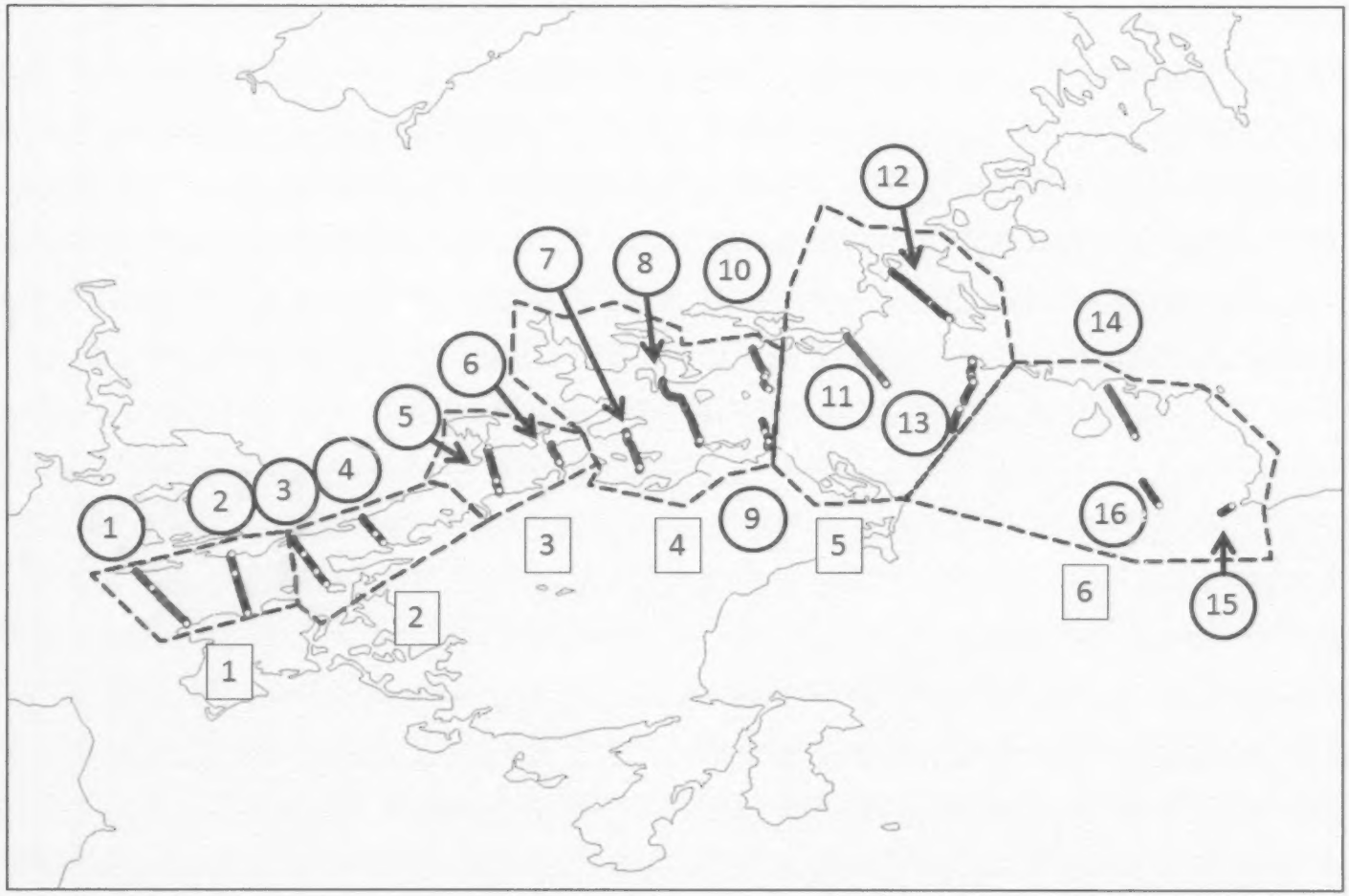

Figure 2: The survey area divided up into six zones (numbers in rectangles). The towfish transects are indicated by numbers in circles.

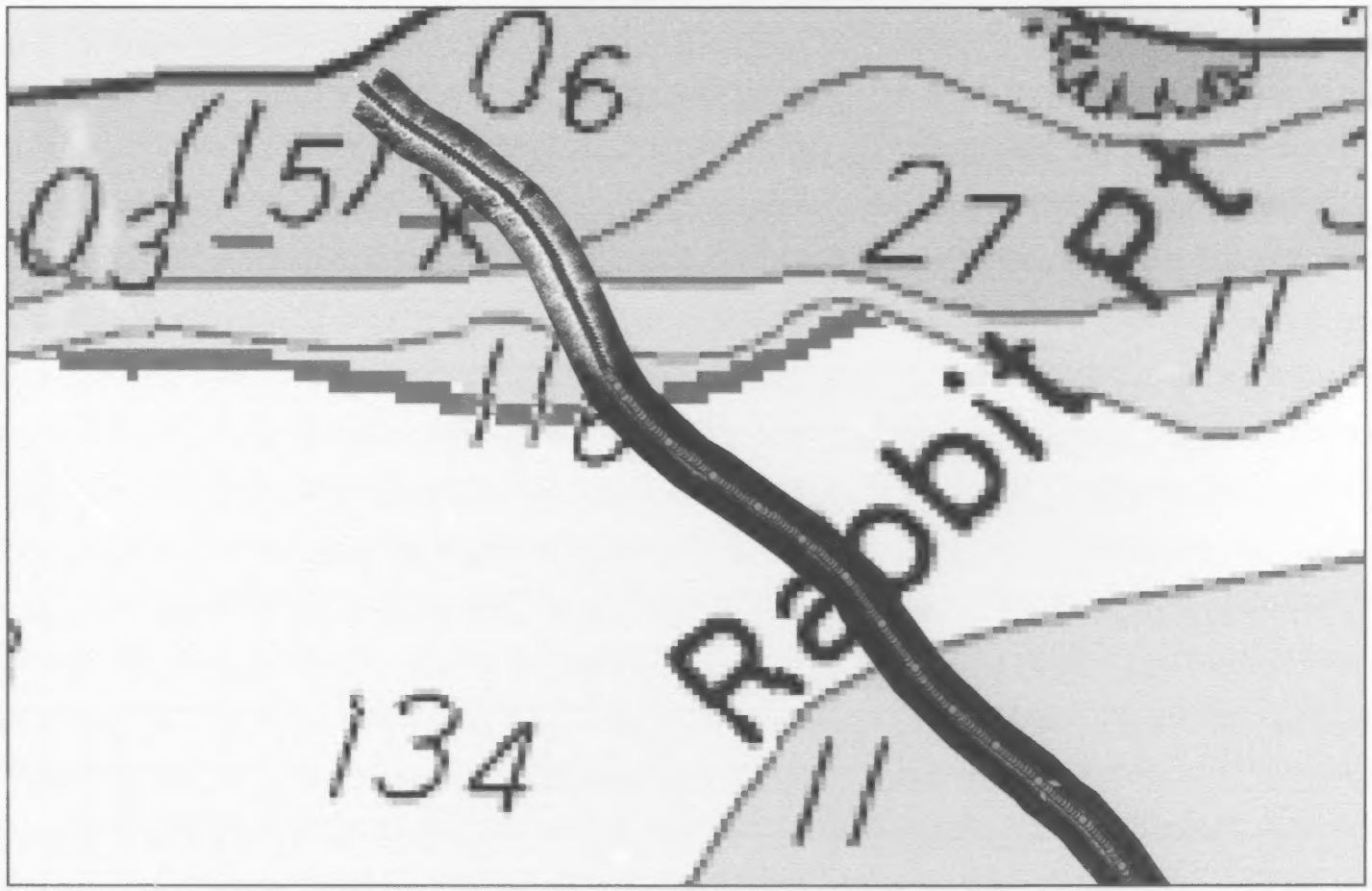

Figure 3: Typical results of towfish bottom type data embedded into the GIS. Sidescan image with bottom classification in mid-line (olive circles = soft sediment; blue stars = coarse gravel; the red chevron indicates the direction of the towfish haul and the position of the associated video clip). The width of the sidescan image is 30m. Transect T1.

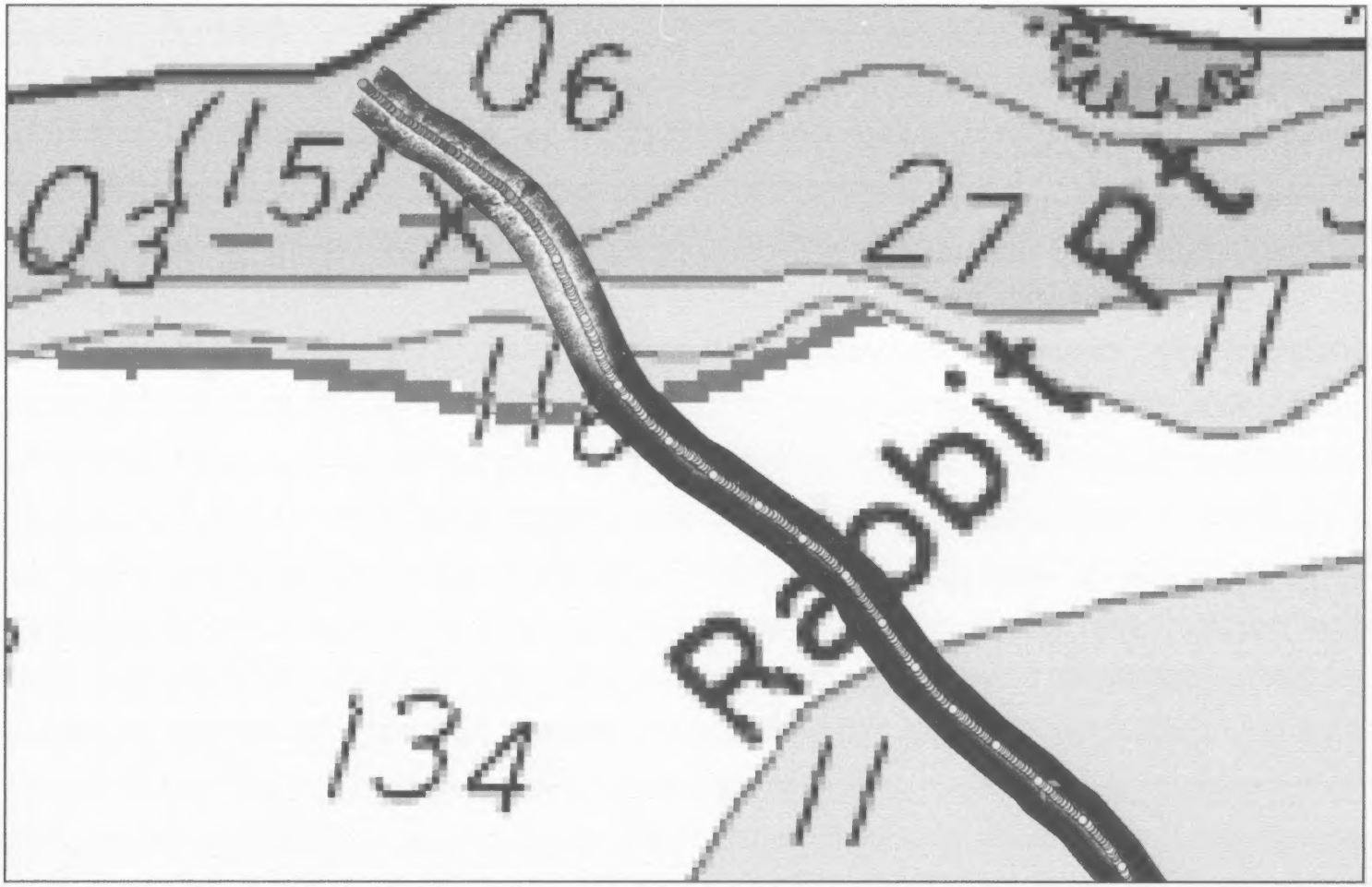

Figure 4: The same towfish track as Fig. 3 with the macrophyte classification (light blue circles = 100% bare substrate; green = *Saccharina* dominated; red = *Fucus* dominated; dark blue = *Zostera* dominated).

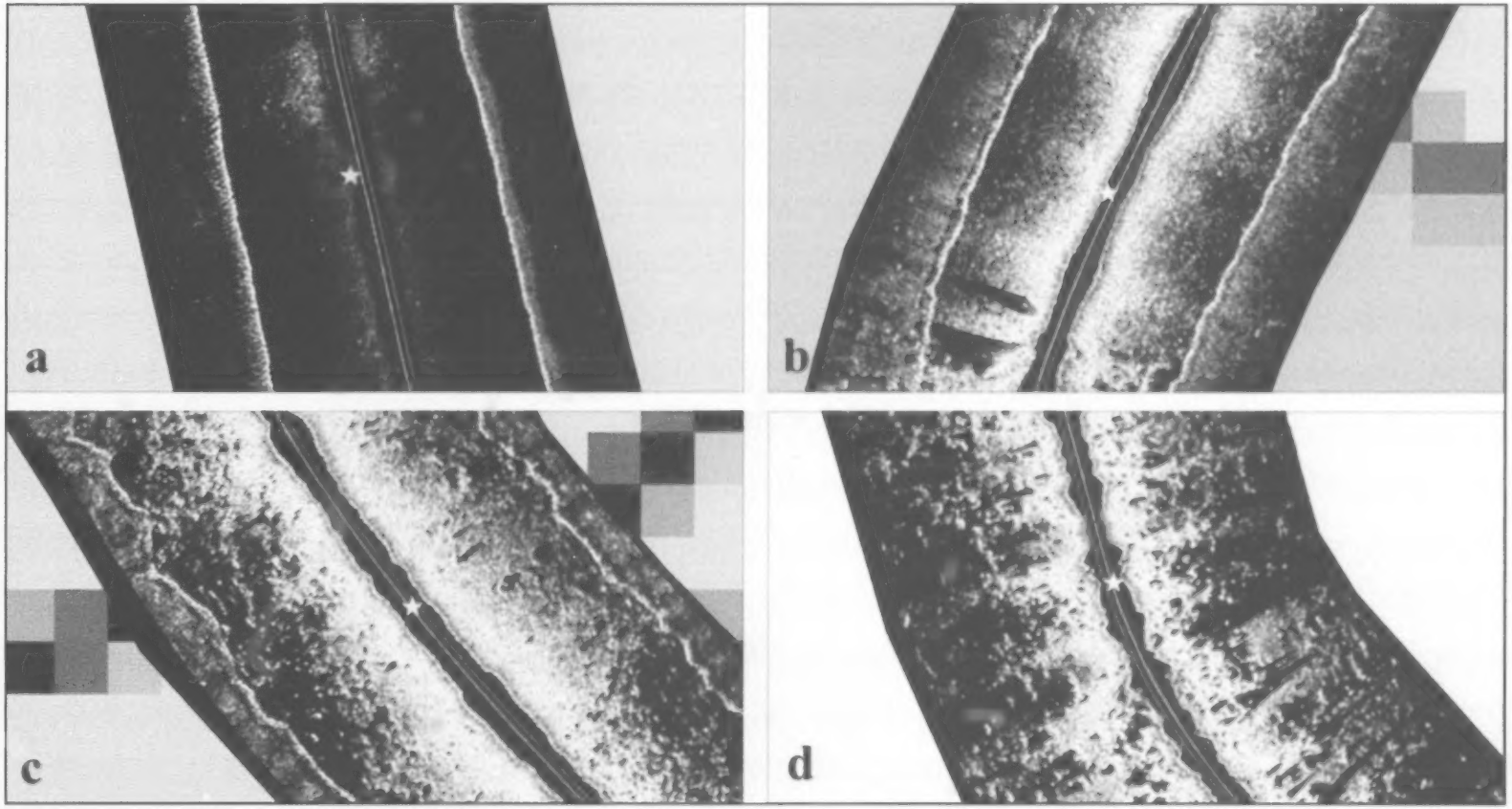

Figure 5: Sidescan imagery associated with different bottom types (each image is 30m wide). **a** mud bottom (T8S7). **b** coarse sand with pebble (T10bS1). **c** gravel base with scattered cobble (T11S2). **d** boulders and cobble on gravel (T16aS2).

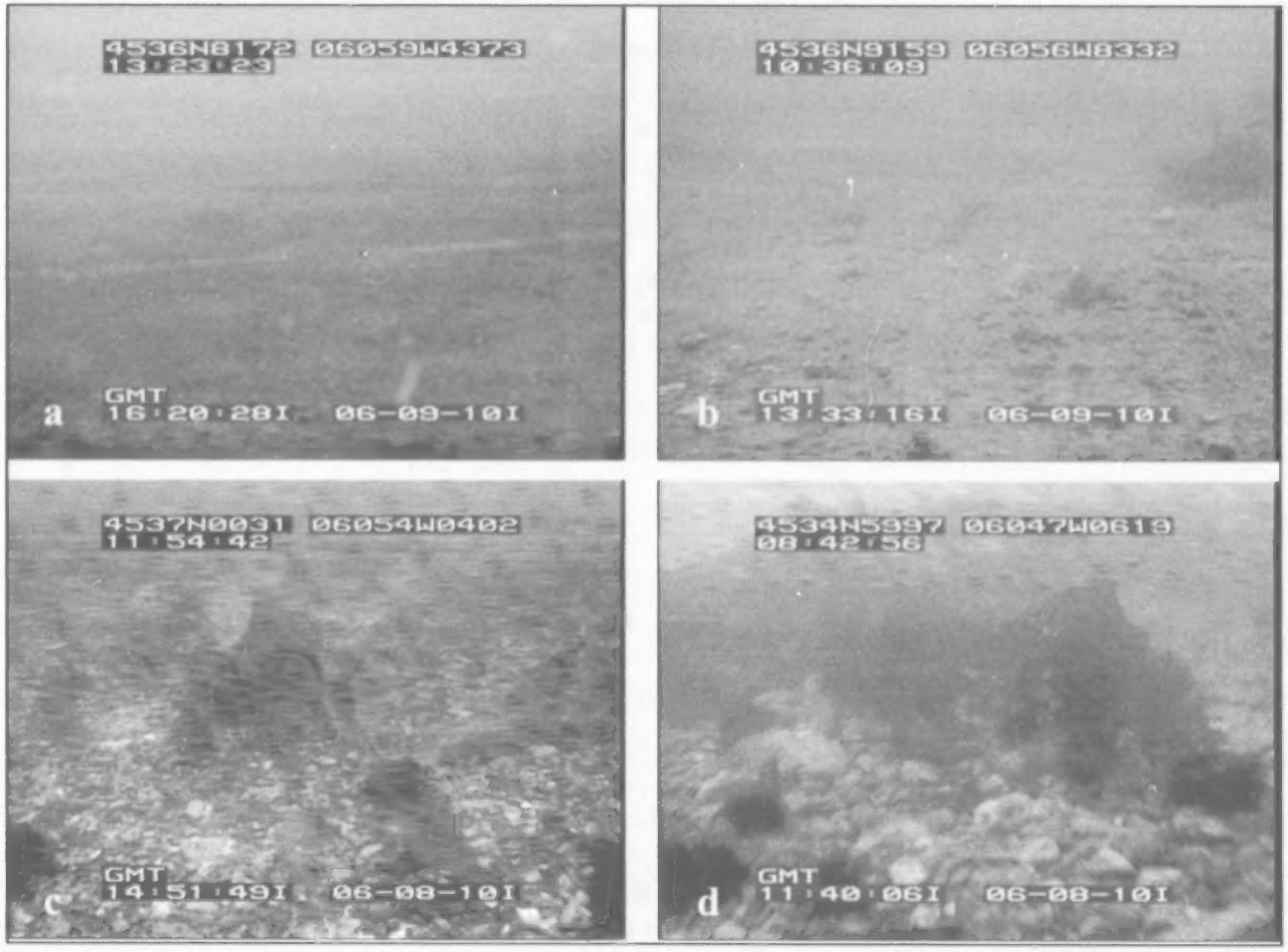

Figure 6: Bottom type screen shots from the towfish video (10 cm red scaling laser, latitude and longitude in degrees decimal minutes at top of each image, GMT time and date stamp on bottom). **a** mud bottom (T8S7). **b** coarse sand with pebble (T10bS1). **c** gravel base with scattered cobble (T11S2). **d** boulders and cobble on gravel (T16aS2).

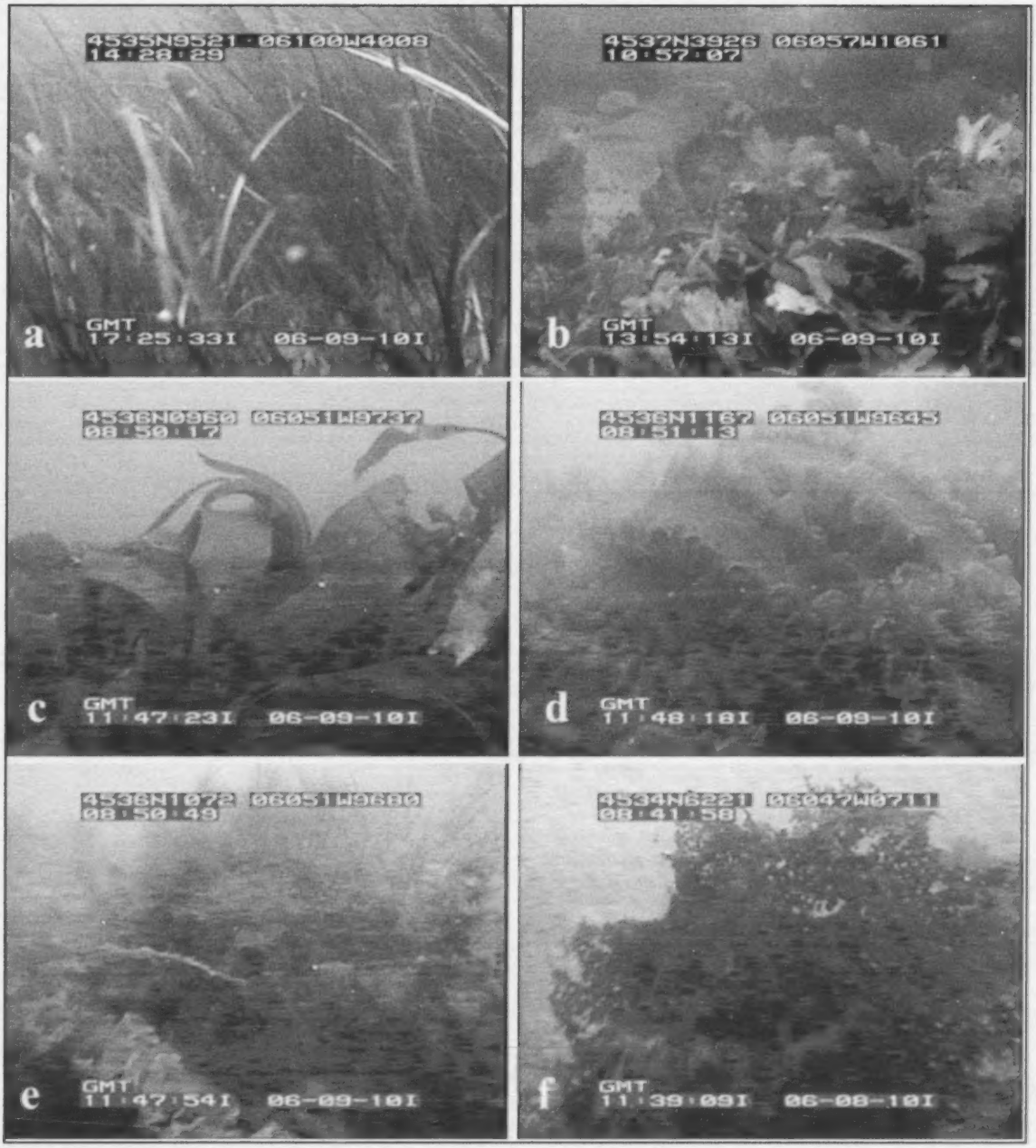

Figure 7: Macrophyte screen shots from the towfish video. **a** eelgrass, *Z. marina* (T4S4). **b** *F. serratus* (T10bS3). **c** *L. digitata* (T13S2). **d** *S. latissima* (T13S2). **e** *Desmarestia* (T13S2). **f** *Agarum* (T16aS2).

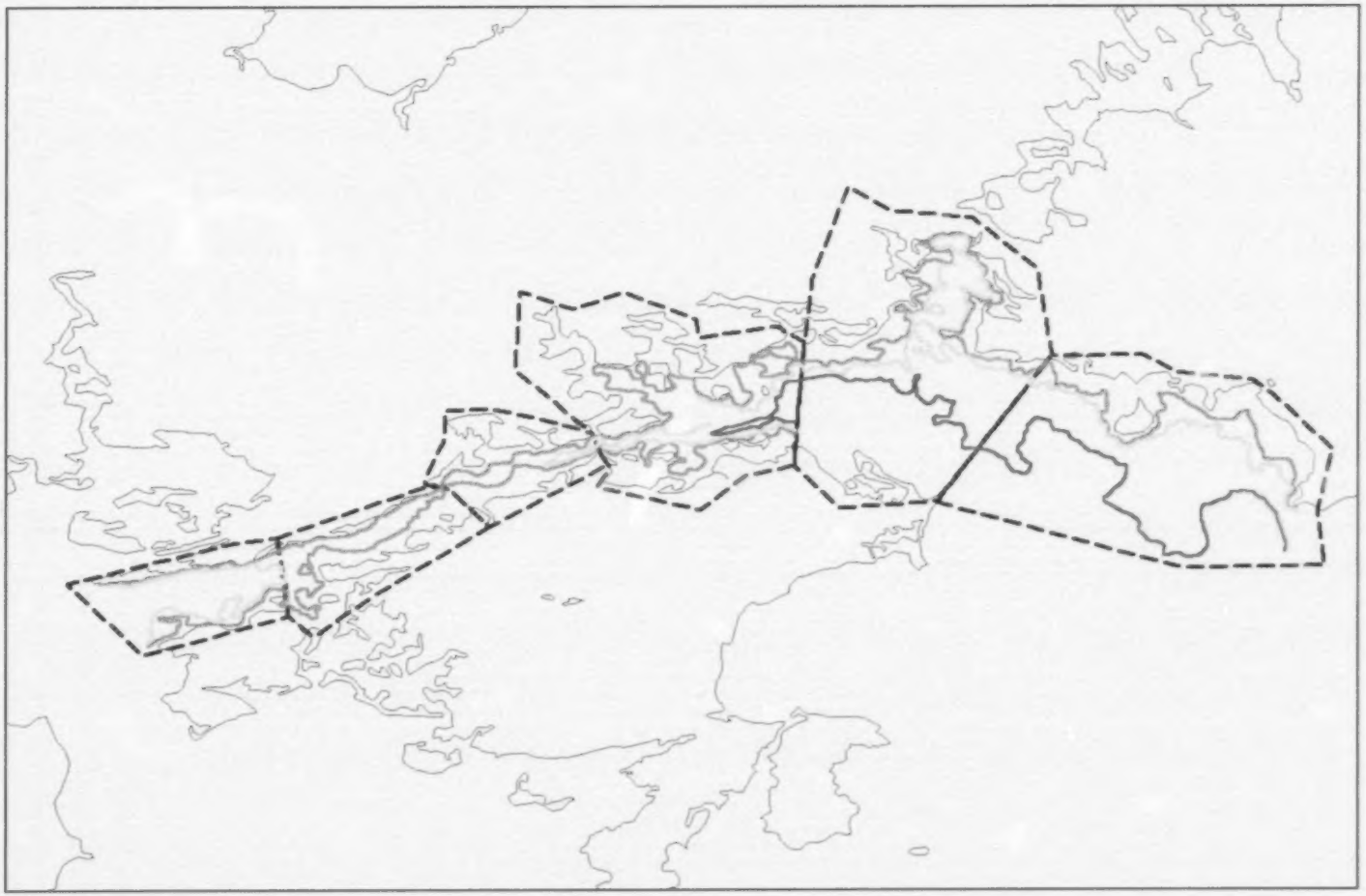

Figure 8: The survey area indicating the tracks of the echosounder data acquisition. The tracks followed three different depth contours, 5m (red), 10m (green), and 20m (blue).

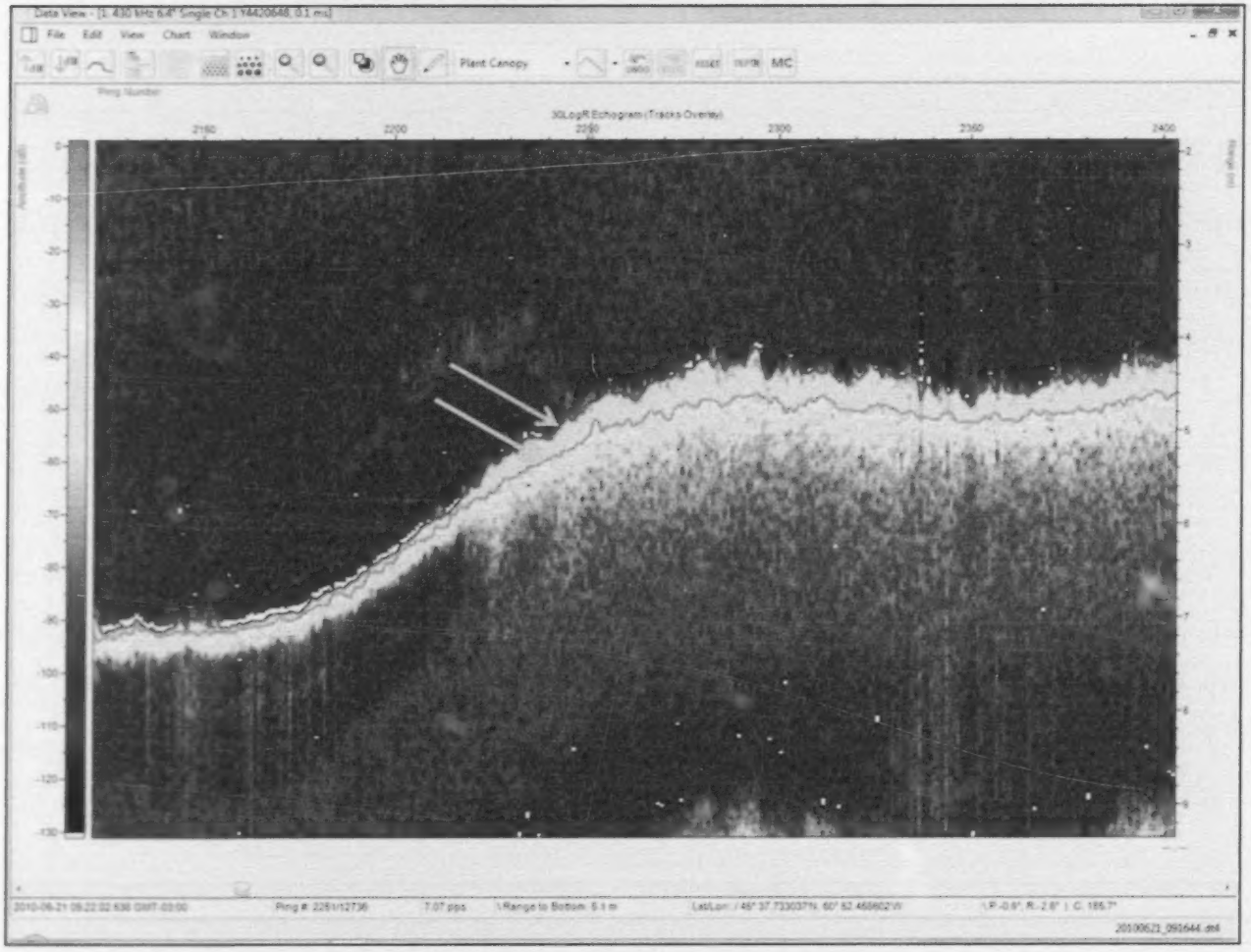

Figure 9: Screen shot of VH bottom detection line (orange arrow) and macrophyte detection line (green arrow). The light green region between these two lines represents the macrophyte canopy.

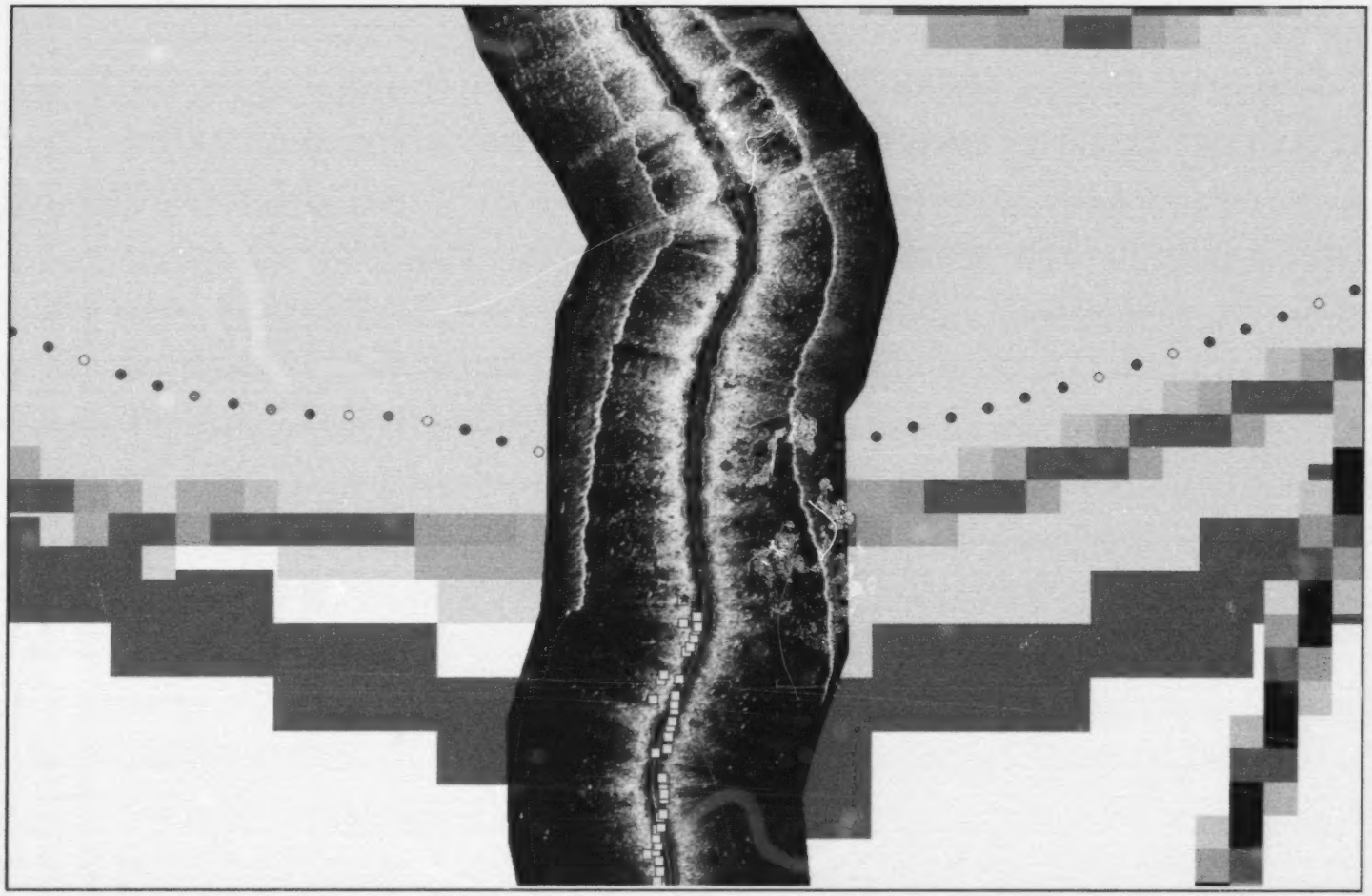

Figure 10: VH bottom classification crossing north end of towfish transect T7 near the 10m contour line. The towfish bottom classification (coarse gravel, blue stars) matches the VH classification (coarse gravel / sand or silt, blue circles) at the cross point.

Figure 11: Ground truthing for VH macrophyte canopy classification. Same location as Fig. 10. The towfish classification (*Saccharina*, green circles) is consistent with the VH canopy height classification of 0.5 to <1.6m at the cross point (green circles). Canopy height was slightly lower on either side of the cross point (yellow circles, 0.2 to <0.5m) but still consistent with a signal from a larger algal thallus.

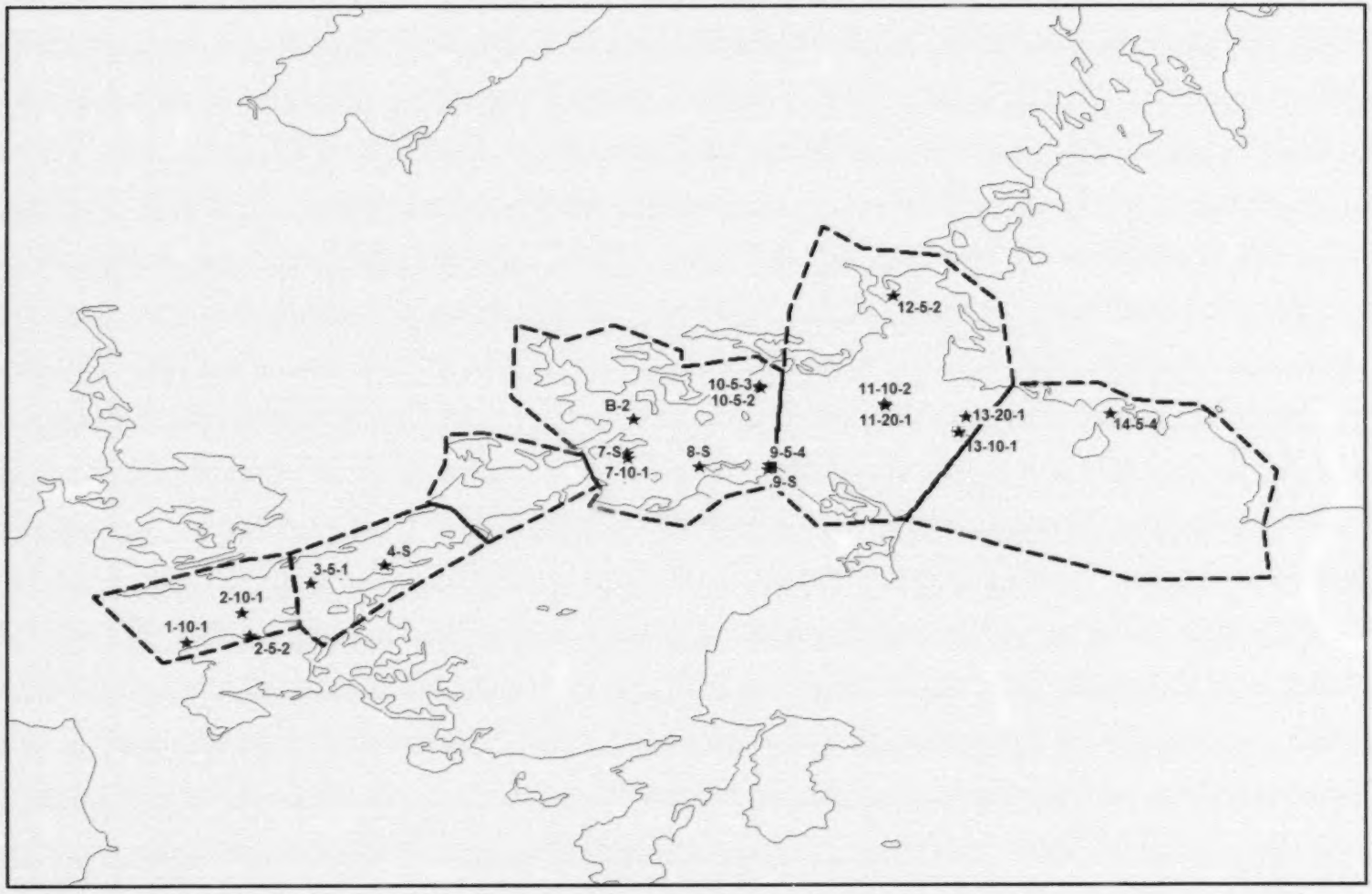

Figure 12: Sampling stations. The coding is transect number-depth-sample number. (e.g. 1-10-1 is transect T1 at 10m depth, sample number 1). Shore stations identified by 'S'.

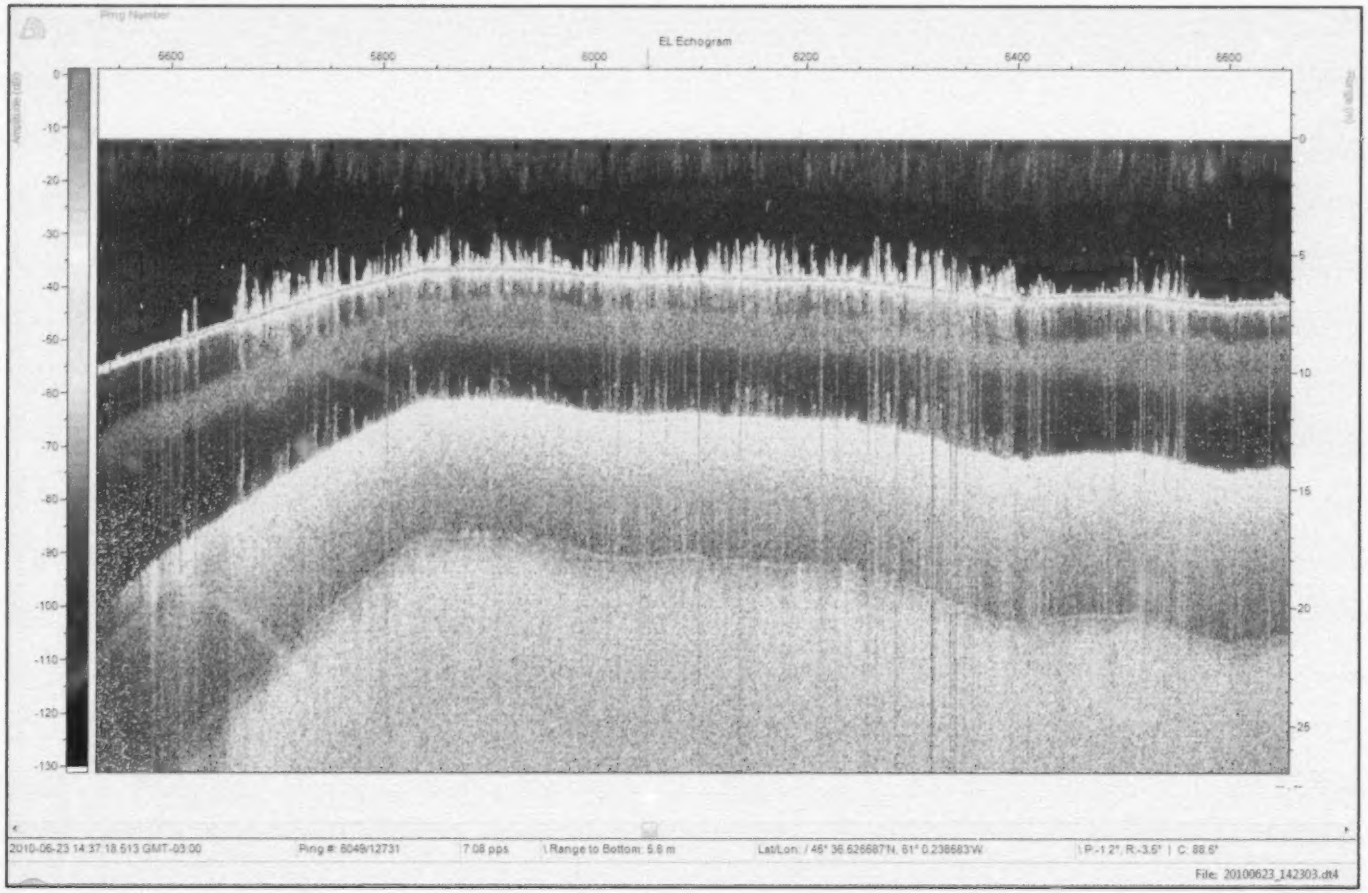

Figure 13: Echogram indicating large thalli of *S. latissima* with crozier morph at station B-2. The range scale on the right indicates that many of these thalli are close to 2m tall.

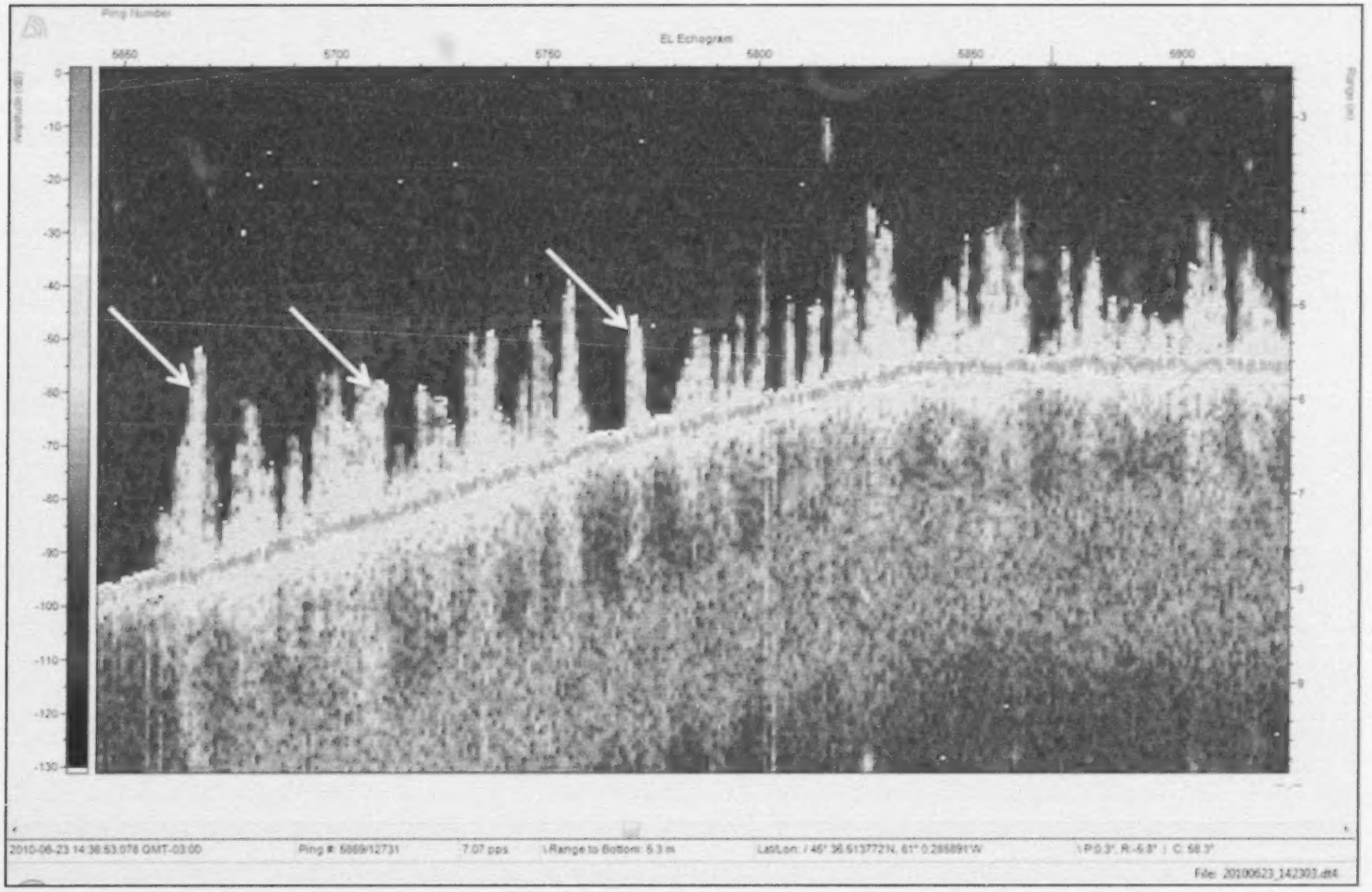

Figure 14: Detail of echogram in Fig. 13. The more acoustically reflective areas near the top of many of the macrophyte echogram images (arrows) are consistent with the air filled stipe apex typical of the crozier morph of *S. latissima*. The large thallus takes the form of an inverted 'V' where the stipe floats upright from its holdfast and the fronds then hang downwards from the stipe apex.

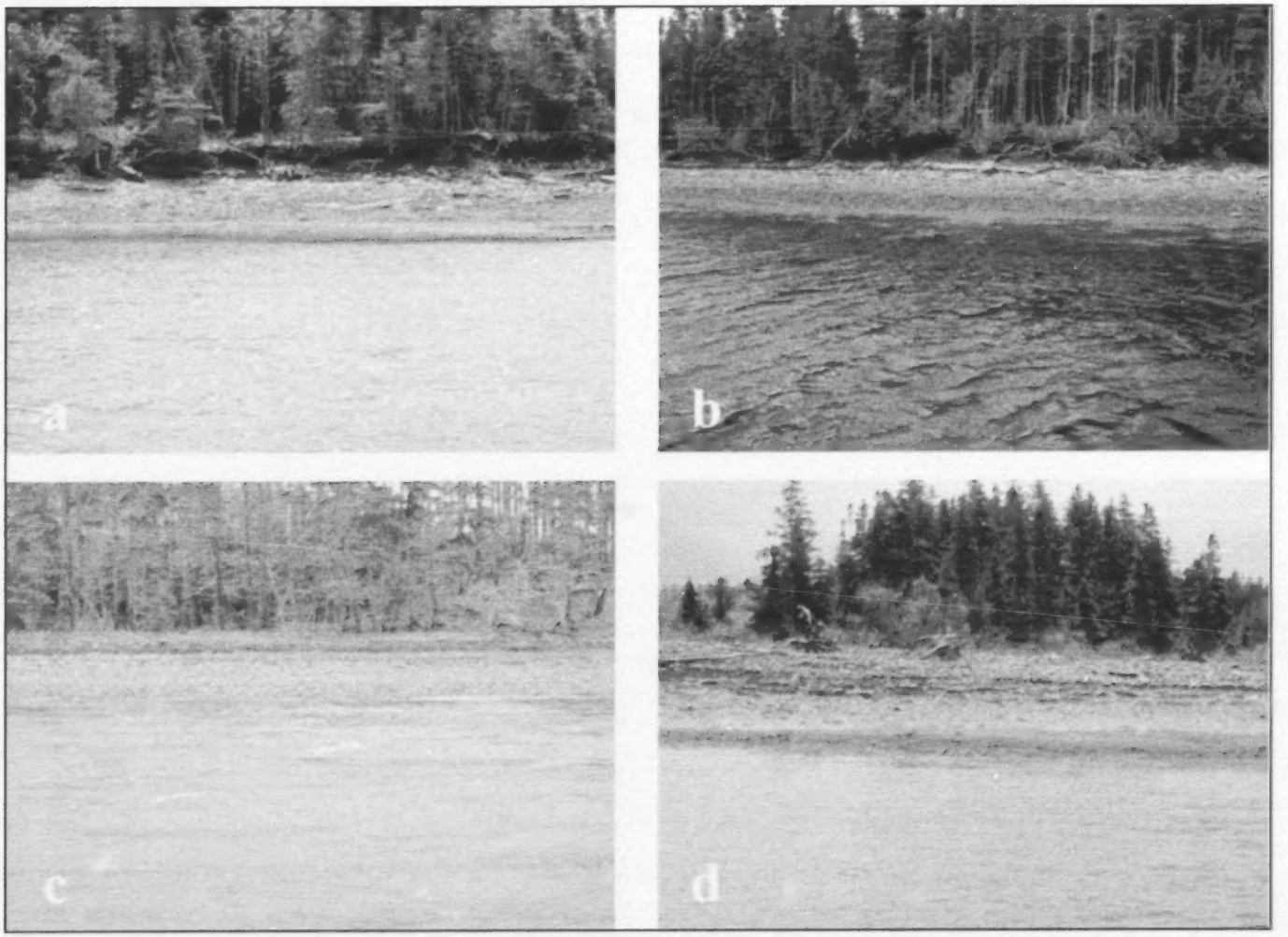

Figure 15: Shore stations. **a** 4-S (June 10, 2010). **b** 7-S (June 9, 2010). **c** 8-S (June 9, 2010). **d** 9-S (June 9, 2010).

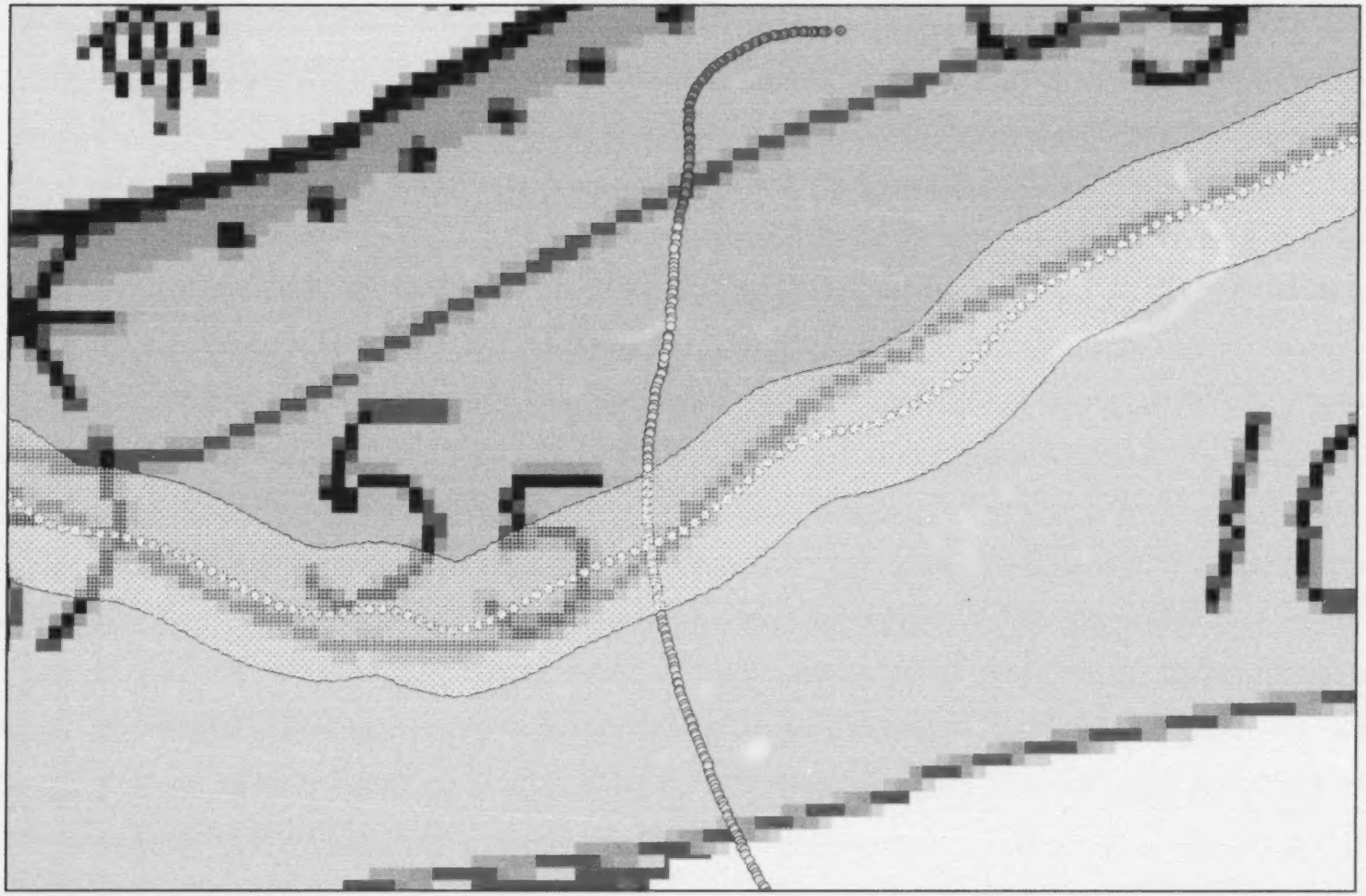

Figure 16: Example buffer created along the 5m VH scores for canopy height near the north end of T1. Total buffer is 40m wide (20m on either side of the score points).